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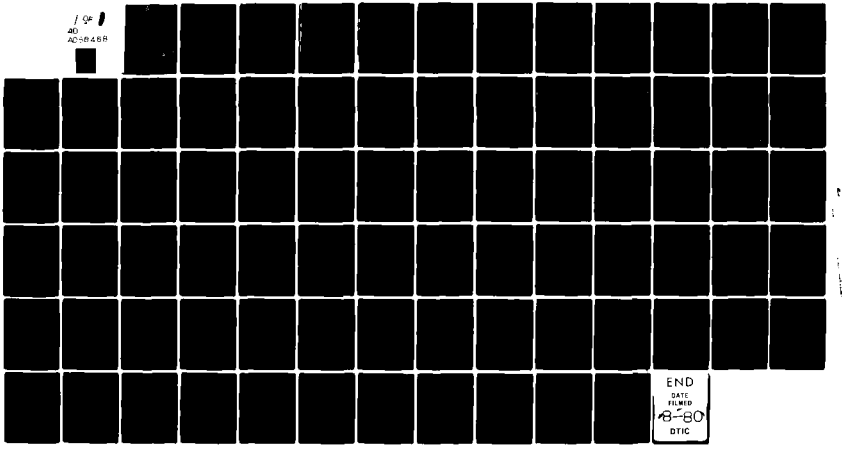

Biological Effects of Nonionizing Electromagnetic Radiation

VOLUME IV

NUMBER 4

JUNE, 1980

A DIGEST OF CURRENT LITERATURE

A Quarterly Publication Produced for
National Telecommunications and Information Administration
and United States Navy

FRANKLIN RESEARCH CENTER
Science Information Services Organization

ERRATA SHEET

Biological Effects of Nonionizing Electromagnetic Radiation
Volume 4, Number 4
June, 1980

Page	Correction
2, line 26, left-hand column	For (11): 5; January 1980 read (12): 5; February 1980
14, line 13, right-hand column	For 10-76-9/79 read 10/76-9/79

BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION

A Digest of Current Literature

A Quarterly Publication Produced for
National Telecommunications and Information Administration
and United States Navy

Literature Selected and Abstracted
by
Biomedical Group, Science Information Services Organization

Bruce H. Kleinstein, Ph.D., J.D., Project Manager

Sheryl A. Dyner, Managing Editor

BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

June, 1980 Volume IV, Number 4

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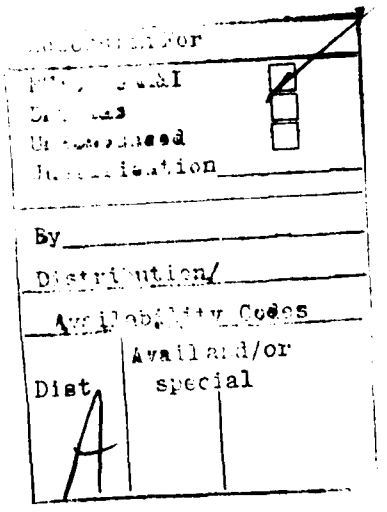

PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract to the National Telecommunications and Information Administration (NTIA); funding provided by the U.S. Navy under interagency agreement with NTIA.

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and other radio frequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of the service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume IV, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)
Å - angstrom(s)
BRH - Bureau of Radiological Health
C - centigrade
cm - centimeter(s)
cps - cycles per second
dB - decibel(s)
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
g - gram(s)
G - Gauss
GHz - gigahertz
HEW - Health, Education, and Welfare
hr - hour
Hz - hertz
IEEE - Institute of Electronic and Electrical Engineers
IMPI - International Microwave Power Institute
IU - international unit(s)
J - joule(s)
k - kilo--
l - liter(s)
m - meter(s)
m - milli--
M - mega--
mho - unit of measurement of conductivity
min - minute(s)
mo - month(s)
n - nano--
NBS - National Bureau of Standard
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for Occupational Safety and Health
NTIA - National Telecommunications and Information Administration
NTIS - National Technical Information Service
Oe - oersted(s)
OSHA - Occupational Safety and Health Administration
OTP - Office of Telecommunications Policy
PHS - Public Health Service
rad - radiation absorbed dose
R - roentgen(s)
rpm - revolutions per minute
sec - second(s)
USAFSAM - U.S. Air Force School of Aerospace Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet
V - volt(s)
VA -Veterans Administration
W -watt(s)
Wb - Weber(s)
WHO - World Health Organization
wk - week(s)
wt - weight
yr - year(s)

μ - micro--

FIBER OPTIC THERMOMETER PLUS MICROWAVE HEATING USED TO COMBAT LOCALIZED TUMORS

A fiber optic thermometer small enough to inject into the body through a hypodermic needle has been developed by scientists at RCA Laboratories to aid in cancer treatment. The cancer treatment technique, which uses microwave-induced heat to combat localized tumors, is currently being tested in a variety of hospitals and laboratories around the country. In addition, the device is also being tested in the laboratory for use in microwave oven measurement and calibration. Jacob M. Hammer and Clyde C. Neil were awarded one patent and Mr. Hammer alone was awarded another for the fiber optic device, which unlike conventional metal and glass thermometers does not interfere with the propagation of microwaves. Accurate temperature measurements at specific points within the body allow malignancies to be more easily located. The microwave applicators allow heat to be focused into the specific areas where the cancers are located. The tumors, because of their poorly developed vascular system and inability to effectively dispel heat, succumb to temperatures greater than 42 C. RCA is now experimenting with coaxial applicators designed for insertion into body cavities.

Opt. Spectra 14(1): 16, 18; 1980.

COMBINED RADIOMETRY AND MICROWAVE TECHNIQUE IS BEING TESTED TO SEEK AND DESTROY CANCER

A microwave system that uses noninvasive techniques to diagnose and treat cancer has been developed by Microwave Associates, Inc. of Burlington, MA. This system, for the first time, couples radiometry and differential hyperthermia into one device. The unit consists of an extremely sensitive radiometer receiver that measures temperature deviations of less than 0.1 C and a transmitter that couples microwave energy into the body. Detection is performed with a 4.7-GHz receiver. The transmitter operates at 1.6 GHz to prevent interference with the radiometer; the lower frequency also provides deeper heating. A ridged waveguide in contact with the body couples the energy and contains the radiometer pickup. The system's detection capabilities are currently being evaluated with cancer patients at the Norfolk (VA) General Hospital by Dr. Anas El-Mahdi and Dr. James Shaeffer of the Eastern Virginia Medical School. In one patient, the system has been used to successfully pinpoint a cancer not positively identified by conventional methods. Ken Carr, senior Vice-President of Microwave Associates, Inc., explained that to date "tumors less than 1 cm in diameter at depths of 3 cm have been located." In addition, since temperatures above 42 C are reported lethal to cancerous tissue, the unit may be useful for treatment of cancer due to the differential heating effects of microwaves. The researchers expect the clinical work to take about two more years and they anticipate an additional one or two years before production.

Microwaves 19(1): 17, 20; 1980.

MICROWAVE TECHNIQUE TO SCREEN FOR BREAST CANCER IS BEING TESTED

A method that uses microwaves to detect breast cancer, which eliminates the need for exposure to potential cancer-causing radiation, is being tested, according to Dr. Earle Gregg, professor of radiology, Case Western Reserve University School of Medicine, Cleveland, OH. By measuring the strength of the microwaves as they pass through the breast tissue, a 2-dimensional computerized picture of the area is composed that differentiates healthy tissue from cancerous lesions. Testing of the technique is still in the early stages, and as yet cannot detect tumors less than 0.5 cm in diameter.

Fam. Health 12(1): 19-20; 1980.

BRH REPORTS ON INEXPENSIVE MICROWAVE SURVEY DEVICES

A recent BRH report, "Inexpensive Microwave Survey Instruments: An Evaluation," questions the technical feasibility of these devices and discusses their potential in the consumer market. The report, prepared by William A. Herman and Donald M. Witters, Jr. of BRH's Division of Electronic Pro-Products, presented the results of tests performed on four sample low-cost detectors: the Micromate (Princeton Microwave and Testing, Inc., Princeton, NJ), the Guard-Rod (Tanray Associates, Inc., Elberon, NJ), the Interceptor (Electrobits Pty., Ltd., Australia), and the Microscan (Birene Medical Supplies Pty., Ltd., Australia). The tests were conducted in front of a slot radiator by comparison to calibrated reference survey meters; the parameters tested included calibration, polarization ellipticity, and amplitude modulation sensitivity. The BRH report contends that "there are serious questions about the ability of these devices to distinguish oven leakage levels which exceed [government standards] from lower levels which do not." According to Samuel Sperling, BRH information chief, the agency would question the need for these low-cost devices even if the tests had shown 100-percent accuracy. One manufacturer (Tanray Associates, Inc.) in a publicity release has expressed doubt over the stringency of the BRH regulations. The manufacturers have established a market for such low-cost microwave survey devices; according to other manufacturers, the devices "are intended for use by consumers as an initial check for potentially dangerous leakage from microwave ovens." Metrifast of New Hyde Park, NY markets the device by direct consumer appeal and through wholesalers in the restaurant trade by telling restaurant owners

that "it's good management to demonstrate safety of their ovens by using the detector." In Sperling's view, however, the agency has carefully set the existing standards and has enforced them adequately by periodic inspection of microwave oven manufacturing facilities. He adds that he is confident "that microwave ovens pose no danger to the consumer."

Microwaves 19(3): 15-16; 1980.

VEXILAR TO MARKET NEW LOW-COST MICROWAVE LEAKAGE DETECTOR

The Commonwealth Scientific and Industrial Research Organization, an agency of the Australian government, has developed a new low-cost microwave leakage detector. The device, a hand-held unit containing a light-emitting diode that glows red on contact with microwave radiation greater than 5 mW/cm^2, will be marketed in North America by Vexilar, Incorporated. Proposed uses for the device include: detection of leakage from misused or damaged microwave ovens, during diathermy treatment, and near industrial microwave heaters that operate in the industrial, scientific, or medical band.

Bioelectromagnetics Society Newsletter (11): 5; January 1980.

DOCTORS DISCUSS ELECTROMAGNETIC FIELDS AS BIOLOGIC STRESSORS AT THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ANNUAL MEETING

Dr. A. A. Marino and Dr. R. O. Becker of the VA Medical Center of Syracuse, NY discussed the role of environmental electromagnetic energy fields as biologic stressors at the annual meeting of the American Association for the Advancement of Science (held in San Francisco, CA). The doctors told participants at the meeting that "the clinical signs they [electromagnetic fields] produce in specific individuals depend on the predisposition of the individual and the nature of other stressors in the environment." They indicated that minor research efforts on such effects have been initiated and that even ordinary household devices such as electric blankets, hair dryers, and food mixers are being investigated.

Ind. Week 204(5): 35; 1980.

NO ILL-EFFECTS FROM MICROWAVE RADIATION DEMONSTRATED IN NAVY MEN

A study contracted by the BRH of 40,000 Navy enlisted men who worked with radar while serving in the Korean War from 1950 to 1954 was conducted. Exposure was assessed in 20,000 electronic equipment repairmen (for whom potential exposure was maximal) and 20,000 equipment operators (for whom potential exposure was minimal); the parameters studied included occupational duties, length of time on the job, power of equipment at the time of potential exposure, later causes of death, hospitalization while in the Navy, later hospitalization in VA facilities, and disability compensation. No adverse effects from microwave exposure were demonstrated. There were no unusual patterns of hospitalization for illness during the time of exposure, nor were any effects on long-term mortality rates observed. The BRH noted, however, that the study was limited since the extent of hospitalization outside Government facilities, the reproductive performance of the 40,000 servicemen, the health of their children, and the individual employment histories after leaving the service were not determined.

FDA Consum. 13(5): 31; 1979.

"ELECTRIC SMOG" EFFECTS STUDIED IN SWINE

Researchers at Battelle's Pacific Northwest Laboratories are conducting an investigation, sponsored by the Electric Power Research Institute, on the effects of electric fields on pigs. Forty Hanford miniature swine have been exposed to electric fields of 30 kV/m at 60 Hz for 20 hr/day for periods ranging from 6 to 14 mo; 40 nonirradiated swine housed under otherwise identical conditions served as controls. Thus far, no obvious ill-effects of exposure have been observed. According to Dr. Richard D. Phillips, manager of the study, "all the animals have bred and delivered 140 offspring," and there has been "no apparent alteration in the growth and development of either the parents or the offspring." In addition, no "abnormalities in the offspring as a result of [their] being born within electric fields" have been demonstrated. Dr. Phillips expects to have usable data on the effects of electric fields on hematology, serum chemistry, immunology, teratology, cytogenetics, pathology, behavior, and general growth and development by the spring of 1981.

Ind. Res. Dev. 22(2): 72; 1980.

CONCERN EXPRESSED OVER THE POSSIBLE HEALTH EFFECTS OF "MAGNETIC SMOG"

A research team headed by Antony C. Fraser-Smith of the Stanford Radioscience Laboratory has conducted experiments that demonstrate that the California Bay Area Transit System (BART) increases background levels of magnetic fields at ultra-low frequencies by 100-1,000 times at about 100 m from the track. According to the team's experiments, a current loop is generated each time a train accelerates or decelerates, causing a fluc-

tutation in the magnetic field ("magnetic smog"). Mr. Fraser-Smith expressed concern about the effects that this fluctuation or increase in the magnetic field may have on people living near the 115-km long BART system: "There is some evidence to indicate that the reaction time of human beings is affected by increased exposure to magnetic fields. The BART frequency range overlaps the frequency range of the human brain, and it may add to or subtract from the brain-generated frequency and 'confuse' the person." Mr. Fraser-Smith added, however, that it is difficult to predict what effects this magnetic smog may have on humans, as only a few studies have been completed on the subject thus far. He admits that the effect is not large in comparison to the earth's magnetic field, but adds that "nobody knows what the cumulative effect of this kind of radiation--20 hr/day, 7 days/wk--may be on the people in the Bay area."

Ind. Res. Dev. 22(3): 88, 91; 1980.

EPA REQUESTED TO PERFORM ELECTROMAGNETIC ENERGY RADIATION CHECK IN RUTHERFORD, NJ

Congressman Andrew Maguire has requested that the EPA reinvestigate Rutherford, NJ, an area suspected of having high levels of nonionizing electromagnetic radiation. In 1976, an unusually large number of cases of leukemia and Hodgkin's disease was observed at the Pierrepont School in Rutherford; a subsequent State Health Department study confirmed that there was statistically high evidence of leukemia and Hodgkin's disease in the area. After the State Health Department's report, the New Jersey EPA mobilized a task force to look for cancer-causing chemicals and radiation, but found results that were comparable to other similarly industrialized areas. In response to a request by concerned parents, however, Congressman Maguire requested that the NBS conduct a study of the area in May 1979. Measurements of the E-field by the NBS indicated that the value on the highway near the school was 530 $\mu W/cm^2$ and was 2.7 $\mu W/cm^2$ for the school itself. Since these values were higher than those found by the EPA, Congressman Maguire has requested that the EPA conduct a second study, this time measuring field strength, power density, and frequency as well.

Electronic Engineering Times
pp. 1, 81; January 7. 1980.

RESIDENTS ALARMED BY BELL TELEPHONE'S PLANS TO BUILD MICROWAVE TOWERS

Some of the residents of two small Montgomery County communities in Pennsylvania are concerned about Bell of Pennsylvania's plans to build one 120-foot tall microwave tower in each of their communities. Bell officials, supported by an array of scientific testimony, say that the microwave radiation coming from such towers is too weak to pose any health hazard. They argue that the radiation levels are well below safety guidelines and that radiation from similar towers built across the country have harmed no one. Herbert S. Cohen, an administrative law judge with the Pennsylvania Utility Commission, recently issued an opinion that supports Bell's case. However, some of the residents of the communities are not convinced. Some experts are re-evaluating the data on microwave health effects and other government officials are wondering if the present safety standards are strict enough. The problem, health officials say, is that there isn't enough scientific evidence on which to base a standard. Dr. Stephen Cleary, professor of biophysics at the Virginia Commonwealth University, feels that "we should take a conservative attitude and set an interim standard at a low enough level where you stand a good enough chance not to get an effect" and not "wait until something deleterious" has been shown.

Philadelphia Bulletin
January 30, 1980.

SCIENTISTS DEBATE THE USEFULNESS OF THE SAR CONCEPT IN THE DEVELOPMENT OF THE C95 SAFETY STANDARD REVISION

In the November 1979 issue (Number 10) of the *Bioelectromagnetics Society Newsletter*, Allan H. Frey of Randomline, Incorporated (Huntingdon Valley, PA) disputed the use of the specific absorption rate (SAR) concept in the development of the C95 safety standard revision. Frey's article has touched off a flood of comments. Two responses that questioned Frey's conclusions appeared in the January 1980 issue (Number 11)--one from Don R. Justesen, Ph.D., of the VA Medical Center (Kansas City, MO) and one from James W. Frazer, Ph.D., of the University of Texas Health Science Center (San Antonio, TX). Justesen states that "whole-body RF [radio frequency] is a young methodology." He asks can "a limit based only on power density be superior to that based on both power density and absorbed energy?" Dr. Justesen solicits "constuctive suggestions regarding the role of dosimetry--as opposed to densitometry--in a scientifically credible RF protection guide." Two commentaries were also published in the February issue (Number 12) of the newsletter--one from A. W. Guy of the University of Washington (Seattle, WA) that disagreed with Frey's views and from Mays L. Swicord of the BRH (Rockville, MD), that agreed with Frey. Swicord stated that although the SAR is a useful concept and "a great improvement over external exposure in bioresponse quantification..., it should be used in the standard setting process with caution and qualification." A point-by-point rebuttal by Frey to Justesen, Frazer, and Guy also appeared in the February 1980 issue. Frey concluded that his purpose for writing the initial

article was "to initiate public debate and through this to bring out the misuse of the SAR concept."

Bioelectromagnetics Society Newsletter (11): 1, 3, 6, 8; January 1980 and (12): 1, 3, 4, 5, 6; February 1980.

BACTERIA SWIM SOUTH BY A MAGNETITE COMPASS

Bacteria that tend to swim heading south have been discovered in sediments off of New Zealand and Australia by an expedition of scientists that included Richard P. Blakemore of the University of New Hampshire. These south-orienting bacteria are the counterparts of north-orienting bacteria that were first discovered by Blakemore off of the coast of Massachusetts in 1975. These microorganisms, too small to distinguish "up and down" on the basis of gravity alone, synthesize an internal compass of magnetite that orients them to the earth's magnetic field for a sense of direction. These findings about bacteria may have implications in research on homing mechanisms of animals and other microorganisms.

Spokesman-Review, p. A9; February 3, 1980.

TOSHIBA PLANS TO CORRECT MICROWAVE OVENS

The BRH has approved a corrective action plan for 4,158 J. C. Penney (model 5895) microwave ovens produced by the Toshiba Corporation between August 8 and September 6, 1979 that failed to comply with a radiation safety performance standard issued under the Radiation Control for Health and Safety Act. The units were not in compliance because of possible leakage of excess microwave radiation resulting from the misapplication of aluminum tape to cover two small apertures on the chassis of the oven at points where the waveguide is fastened to the top of the oven. Toshiba will correct all units, none of which have been shipped to J. C. Penney stores or consumers, by dispatching technicians to the U.S. to remove the existing tape, to properly apply new aluminum tape, and to test for microwave emission at the point of tape application.

BRH Bulletin 14(1): 6; 1980.

43,000 WHIRLPOOL MICROWAVE OVENS RECALLED

A recall of 43,000 Whirlpool microwave ovens (models REM 7200-2, RFM 7300-1, and RFM 7300-2), manufactured and introduced to consumers since May 1979, was approved by the BRH during December 1979. The units were declared in noncompliance with the microwave oven performance standards because of a wiring problem that was found by Whirlpool in at least two ovens that caused the ovens to operate even with the door open. Two wires were switched, causing the ovens to operate even with the timer off. In fact, once a faulty oven was turned on, it continued to operate until it was unplugged unless the temperature probe was being used, in which case the oven operated until the desired temperature was reached. FDA has issued this Class 1 recall because the likelihood of an oven failure could not be predicted and because of the potential hazards involved. Whirlpool has notified all distributors, has requested the distributors to notify all dealers to stop shipment and sales, and has begun notifying all purchasers by telephone and certified letter. There are approximately 18,000 units under the control of the manufacturer, distributors, and dealers and approximately 25,000 units have been purchased. A press release has been issued describing a test that purchasers can perform to determine if their oven is defective. Owners of defective ovens should notify Whirlpool (800-632-1301; in Michigan, 800-632-2243; and in Alaska and Hawaii, 800-253-1121). Whirlpool will replace all defective ovens.

BRH Bulletin 14(1): 6-7; 1980.

ITEMS FROM THE COMMERCE BUSINESS DAILY

☐ **DEVELOP A PLAN FOR FUNDAMENTAL RESEARCH IN ELECTROMAGNETIC RADIATION CHARACTERISTICS FOR RENEWABLE RESOURCES AND FEATURES.**

The National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX 77058 has contracted with the Colorado State University, Fort Collins, CO 80523 for the above study. (February 25, 1980)

☐ **RADAR MEASUREMENTS IN AGRICULTURAL APPLICATIONS.**

The National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, Houston, TX 77058 has contracted with the University of Kansas Center for Research, 2291 Irving Hill Drive, Lawrence, KS 66045 for the above study. (February 25, 1980)

☐ **IDENTIFICATION OF POTENTIAL HUMAN STUDY POPULATIONS FOR NONIONIZING RADIATION HEALTH EFFECTS.**

The Environmental Protection Agency, Contracts Management Division, MD-33, Office of Administration, Research Triangle Park, NC 27711 is soliciting proposals for the above study. The Environmental Protection Agency has a requirement to identify and characterize potential human study populations for health effects of exposure to nonionizing radiation. (April 10, 1980)

NORTH AMERICAN RADIO SCIENCE MEETING AND IEEE/AP-S INTERNATIONAL SYMPOSIUM

Date: June 2-6, 1980
Place: Quebec, Canada: Universite Laval, Cite universitaire
Sponsor: Institute Electrical and Electronic Engineers Antennas and Propagation Society (IEEE/AP-S), International Union Radio Science
Requests for Information: Professor J. A. Cummins, Departement de genie electrique, Universite Laval, Cite universitaire, Quebec, Canada G1K 7P4

Selected Bibliography of Papers to be Presented:

DEVELOPMENTAL ANOMALIES INDUCED BY PULSED MICROWAVE RADIATION. G. d'Ambrosio, F. A. Di Meglio, G. Ferrara, A. Tranfaglia

IRRADIATION OF PROLATE SPHEROIDAL MODELS OF HUMANS AND ANIMALS IN THE NEAR FIELD OF A SMALL LOOP ANTENNA. A. Lakhtakia, M. F. Iskander, C. H. Durney, H. Massoudi

THE USE OF RECTANGULAR GUIDES FOR RADIATION OF STRATIFIED MEDIUM--APPLICATION TO SOME BIOMEDICAL PROBES. J. Audet, J. Ch. Bolomey, Ch. Pichot, M. Robillard, M. Chive, Y. Leroy

EDGE-TRACKING OF CARDIAC STRUCTURES. A METHOD FOR TRACKING OF THE EDGES OF CARDIAC STRUCTURES. J. Kuhfeld, L. Roemer, G. Malindzak

FREQUENCY DOMAIN PROFILE RECONSTRUCTION FOR TISSUE CHARACTERIZATION. C. Q. Lee, L. F. Sio

ELECTROMAGNETIC EARTH INDUCTION FROM AN OVERHEAD LINE CURRENT PARALLEL TO THE GROUND. O. A. Aboul-Atta, L. Shafai, M. Z. Tarnawecky

EFFECT OF A BURIED CABLE ON THE FIELDS OF A VMD ON THE GROUND SURFACE. A.Z. Botros, S. F. Mahmoud

MEASUREMENT AND ANALYSIS OF CONTROLLED POWER-LINE VLF RADIATION FROM THE HV-DC LINE FROM RADISON TO DORSEY, MANITOBA. W. M. Boerner, W. R. Goddard, J. Cole, C. Thio

THIRD INTERNATIONAL SYMPOSIUM ON CANCER THERAPY BY HYPERTHERMIA, DRUGS, AND RADIATION

Date: June 22-26, 1980
Place: Fort Collins, CO: Colorado State University
Sponsor: National Cancer Institute, Colorado American Cancer Society, Journal National Cancer Institute, University Utah, Colorado State University
Requests for Information: Office of Conferences & Institutes, Rockwell Hall, Colorado State University, Fort Collins, CO 89523

Selected Bibliography of Papers to be Presented:

HYPERTHERMIA AND ELECTRON AFFINIC COMPOUNDS. G. E. Adams

HEAT TRANSFER MECHANISMS AND THERMAL DOSIMETRY. H. F. Bowman

APPLICATIONS OF MICROWAVE, ULTRASOUND AND RADIOFREQUENCY HEATING IN VIVO. J. Hunt

PHYSIOLOGICAL CONSIDERATIONS. C. W. Song

CLINICAL LOCAL HEATING--RF. J. H. Kim

CLINICAL LOCAL HEATING--RF. K. Storm

CLINICAL LOCAL HEATING--MICROWAVES. R. M. Scott

CLINICAL LOCAL HEATING--RF--INTERSTITIAL. M. L. M. Boone, M. Manning

CLINICAL TECHNIQUES AND RESULTS FOR WHOLE BODY HYPERTHERMIA. T. Herman, L. Parks, W. Levin, H. Reinhold

INTERNATIONAL SYMPOSIUM ON THE BIOLOGIC EFFECTS OF ELECTROMAGNETIC WAVES

Date: June 30-July 4, 1980
Place: Near Paris, France: Centre Superieur d'Enseigment des Affaires (CESA), Near Paris, France
Sponsor: International Union Radio Science (URSI), Comite National Francais de Radioelectricite Scientifique (CNFRS), International Radio Protection Agency, Bioelectromagnetics Society
Requests for Information: M. A. J. Berteaud, CNRS, 2, rue Henry Dunant, 94320 THAIS, France
Content: Topics will include the interactions of electromagnetic fields with biologic systems; the industrial and domestic uses of electromagnetic radiations; dielectric properties of living matter: dosimetry; molecular and cellular effects; physiologic, physiopathologic, and genetic effects; behavioral effects; and medical applications, such as hyperthermia and microwave thermography

INTERNATIONAL URSI 1980 SYMPOSIUM ON ELECTROMAGNETIC WAVES

Date: August 26-29, 1980
Place: Munich, West Germany: Technical University Munich
Sponsor International Union Radio Science (URSI)
Requests for Information: Dr. Hans Hochmuth, Postfach 70 00 73, 8000 Munchen 70, West Germany

Selected Bibliography of Papers to be Presented:

ELECTROMAGNETIC COUPLING BETWEEN APERTURES AND BIOLOGICAL STRUCTURES. M. Bozzetti, et al.

DETERMINATION OF ELECTROMAGNETICAL CHARACTERISTICS OF BIOMEDICAL PROBES. J. Audet, et al.

MICROWAVE MEASUREMENTS OF THE COMPLEX DIELECTRIC PERMITTIVITY OF BIOLOGICAL LIQUIDS. B. Bianco, et al.

DETERMINATION OF THE ELECTRICAL POTENTIAL DISTRIBUTION INSIDE A CELL MODEL. L. Gogioso, et al.

REFLECTION OF AN OPEN-ENDED COAXIAL LINE: APPLICATION TO NON-DESTRUCTIVE MEASUREMENT OF MATERIALS. J. Besson, et al.

BIOELECTROMAGNETICS SOCIETY SECOND ANNUAL MEETING

Date: September 14-18, 1980
Place: San Antonio, TX: El Tropicano Hotel
Sponsor: Bioelectromagnetics Society
Requests for Information: Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203
Content: Topics will cover the interaction of electromagnetic energy and acoustic energy with biologic systems, *including behavioral, physiologic,* neurologic, endocrine, developmental, genetic, and cellular and ultrastructural effects. Also included are the dielectric properties of biologic materials, electric field effects, exposure systems, dosimetry, diagnostic and therapeutic applications, interactive mechanisms, instrumentation, hyperthermia, and field pertubations

FIFTH INTERNATIONAL WROCLAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Date: September 17-19, 1980
Place: Wroclaw, Poland: Wroclaw Technical University
Sponsor: Association Polish Engineers, Wroclaw Technical University, Institute Telecommunications, Polish Academy Sciences, International Union Radio Science (URSI), International Electrotechnical Commission (IEC)
Requests for Information: W. Moron, Symposium Secretary General, EMC Symposium, 51-645 Wroclaw 12, Poland
Content: All aspects of electromagnetic compatibility will be covered. Specific topics will include immunity and susceptibility; national and international cooperation in establishing regulations, limits, standards, and specifications; harmful effects of radio frequency energy; and shielding and filtering

FIFTH INTERNATIONAL CONFERENCE ON INFRARED AND MILLIMETER WAVES

Date: December 8-12, 1980
Place: Wurzburg, West Germany
Sponsor: Institute Electrical and Electronics Engineers (IEEE)--Microwave Theory & Techniques Society
Requests for Information: K. J. Button, MIT National Magnetic Laboratory, Cambridge, MA 02139
Content: Sessions will cover the biologic effects of electromagnetic radiation

FOURTH INTERNATIONAL ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

Date: March 10-12, 1981
Place: Zurich, Switzerland: Federal Institute Technology
Sponsor: Association Swiss Electrotechnicians
Requests for Information: Dr. T. Dvorak, ETH Zentrum-KT, 8092 Zurich, Switzerland
Content: Topics will cover the protection of the electromagnetic environment and will include the social and economical impact of electromagnetic compatibility (EMC); electromagnetic pollution, control, and enforcement; national and international cooperation in EMC; immunity of electronic systems; EMC of communications, electric power, and automotion; EMC hazards to vital safety systems; compatibility of medical electronics; biologic effects of radio frequency energy; and shielding and absorptive materials

TENTH L. H. GRAY CONFERENCE

Date: July 13-16, 1981
Place: Oxford, England
Sponsor: Institute Cancer Research
Requests for Information: Dr. R. C. Hill, Institute Cancer Research, Royal Marsden Hospital, Sutton, Surrey, England
Content: The biology and biophysics of radio frequency, microwave, and ultrasonic radiation will be reviewed, particularly with respect to their potential therapeutic value

20TH GENERAL ASSEMBLY OF THE URSI

Date: August 10-19, 1981
Place: Washington, DC: Hyatt Regency Hotel
Sponsor: International Union Radio Science (URSI)
Requests for Information: Executive Secretary, R. Y. Dow, National Academy Sciences, 2101 Constitution Ave., NW, Washington, DC 20418 or (202) 389-6478

0570 TISSUE CULTURE MODELING OF MICROWAVE-INDUCED CATARACTS OF THE EYE LENS. Trevithick, J. R. (Univ. Western Ontario, 1151 Richmond St., London, Ontario, N6A 3K7 Canada).

The development of cataracts in isolated lenses exposed to constant amplitude microwaves (heating) and high energy pulsed microwaves (thermal acoustic effect) is being studied to establish cataractogenic conditions for irradiation and the basis for cataractogenesis in such irradiated lenses. Special procedures will be developed for this research. There is a military medical requirement for research elucidating the etiologic relationships between microwave exposure and opacification of the ocular lens. (funding period 9/78-n/a)

Supporting Agency:U.S. Dept. Defense: Army, Medical Res. and Development Command, Walter Reed Army Inst. Res.

0571 DEVELOPMENT OF SIMULATED HUMAN FAT FOR MICROWAVE DIATHERMY PROGRAM. Cuming, W. R. (Emerson and Cuming, Inc., 869 Washington St., Canton, MA 02021).

Standardized components for the assembly of a microwave human phantom with highly accurate dielectric properties will be developed. The simulated fat material will be developed in the following shapes: a cylinder 8 cm in diameter with a 1-cm wall thickness (arm phantom), a cylinder 17 cm in diameter with a 2-cm wall thickness (thigh phantom), and two planar slabs 30 cm x 30 cm, 1- and 2-cm thick (trunk phantom), respectively. These components will be used in conjunction with simulated muscle material to perform dosimetric studies in support of the microwave diathermy regulatory activities of FDA. Epoxy, loaded with fillers, will be molded into the appropriate shapes. Testing of microwave dielectric properties will be precisely measured at 915 and 2,450 MHz with an emphasis on isotropicity (with respect to electric field polarization during measurement) and physical uniformity. (funding period 9/78-7/79)

Supporting Agency:HEW, PHS, FDA, BRH

0572 MEASUREMENT OF RFR TEMPERATURE DISTRIBUTIONS IN BIOLOGICAL STRUCTURES. Burr, J. C.; Krupp, J. H. (Sch. Aerospace Medicine, Air Force, U.S. Dept. Defense, Brooks Air Force Base, San Antonio, TX 78235).

Air Force personnel are often required to work in environments that may require exposure to radio frequency radiation on an intermittent or periodic basis. A biotechnology base will be developed to assure continued maximum safety for such personnel while allowing essential mission operations. Since it is not feasible to experimentally quantify every combination of frequency, exposure duration, pulse characteristic, etc., theoretical calculations and computer modeling will provide an expedient means for hazard estimation. Existing models that predict power distribution patterns in the head will be tested experimentally utilizing phantoms, cadavers, and specially implanted experimental animals. Predicted values from the model will be compared to in vivo measurements with subsequent refinement of model inputs. (funding period 10/76-3/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0573 FAR-FIELD EXPERIMENTAL MICROWAVE DOSIMETRY. Olsen, R. G.; Grissett, J. D. (Medical Sciences Dept., Naval Aerospace Medical Res. Lab., Navy, Dept. Defense, Pensacola, FL 32508).

An investigation is being conducted to ascertain the amount and distribution of electromagnetic energy deposited in the human body for a given far-field irradiation intensity at microwave frequencies of particular interest to the Navy. In addition, the physical parameters (beam polarization, body posture, and/or ground plane orientation) that produce the worst cases of energy absorption in the human body will be studied. Calorimetry will be used to determine the microwave absorption in realistic models of man and lower animals. The results will be extrapolated to man. Far-field irradiation conditions within anechoic chambers will be used. Temperature probes showing little or no disturbance to microwave irradiation will be implanted in man-size and other phantom models. The phantom models will include simulated muscle and brain tissue and simulated versions of major bones for larger models. Infrared thermometry using a high-resolution thermographic imager will be used to study surface heating patterns of the irradiated subjects or deep heating patterns using planes of separation in the various models. (funding period 7/75-9/84)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0574 MICROWAVE ABSORPTION PROCESSES. Prohofsky, E. W. (Executive Building, Sch. Physics, Purdue Univ., West Lafayette, IN 47907).

The basic modes of interaction between radio frequency radiation and molecular components of living tissue will be investigated using radio frequencies of ≤10 GHz. Microwave spectroscopic measurements will be made on homopolymer deoxyribonucleic acid and ribonucleic acid molecules and selected components of these molecules. The gathered data will be analyzed using mathematical/computer models of the molecules in conjunction with laboratory experimentation. The mathematical models will include detailed Hamiltonians of the molecules under study. Prediction of molecular normal modes with and without radio frequency radiation will be based on solid state physics analysis techniques such as Green's functions. Also, the models will include the effects of tissue water around the macromolecule

and the effects of other molecular moieties such as histones. (funding period 3/79-12/79)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0575 THE EFFECT OF HYPERTHERMIA ON TUMOR GROWTH. Bengmark, S.; Hapstrom, L.; Jonsson, P. (Dept. Surgery, Lunds Universitet, S-22185 Lund 7, Sweden).

A safe and reliable microwave technique for inducing local and systemic hyperthermia in experimental animals is being sought. A method for computerized microwave-induced hyperthermia has been developed. The technique involves the placement of thermocouples (Pt/ir) at different levels and in different tissues of Wistar rats that are with or without transplantable adenocarcinoma (liver or subcutaneous). The animals are kept isolated in a plexiglass cage, which is placed in a larger cage with a constant temperature (25 C). Siemens (Radiotherm 305) magnetron at 2.45-GHz maximum and a 200-W microwave generator are used. The exposure is below 4,000 W/m^2. The temperature probe signal from the animal is digitalized and fed to a computerized control system (INTEL 8085 microprocessor) with a 16-K byte memory. This system directs the microwave generator through a set of relays to a predetermined temperature in the animals of 41.5 C. The setup is quite precise (±0.2 C) especially in relation to predetermined temperature levels, exact duration, and intervals. At a central temperature of 41.5 C for 1 hr, every 8 hr a survival of 7%, without difference between tumor-bearing and nontumor-bearing rats, was seen. Reduced tumor growth during the first 3 days after hyperthermia was also observed. Further studies on the effect of microwave hyperthermia alone or in combination with other treatment modalities (i.e., hepatic artery ligation or infusion of cytostatic agents) on blood circulation, liver function, and reticuloendothelial system function are planned. (funding period 0/79-6/79)

Supporting Agency:Riksforeningen Mot Cancer

0576 DEVELOPMENT OF CHEMICALLY-INDUCED CANCERS IN ANIMALS WITH LONG-TERM EXPOSURE TO LOW LEVEL MICROWAVE FIELDS. Szmigielski, S.; Szudzinski, A.; Pietraszek, A. (Center Radiobiology and Radioprotection, 128 Szaserow, 00909 Warsaw, Poland).

The effects of microwave irradiation of varying frequencies, exposure durations, and power densities on neoplastic transformation of irradiated cells will be investigated in mice. Influence of long-term low-level microwave irradiation on cell mediated immune reactions is also postulated. The development of skin cancer induced by 3,4-benzopyrene in mice exposed for 1-4 mo to nonthermal (5 or 15 mW/cm^2) power densities of 2,450 MHz microwaves (continuous and pulse modulated waves) will be analyzed; irradiation with microwaves will be performed prior to or simultaneously with 3,4-benzopyrene treatment. Cancer development will be evaluated macroscopically and microscopically. The development of primary hepatomas in mice injected intraperitoneally with diethylnitrosamine and exposed to 2,450 MHz microwave field (as above) will also be studied, as will the natural antineoplastic resistance (cancer lung colonies, natural killer activity) in mice exposed to low level microwave fields. (funding period 0/80-11/82)

Supporting Agency:Ministry Health and Social Welfare, Poland

0577 DEVELOPMENT AND GROWTH OF CHEMICALLY-INDUCED AND SPONTANEOUS CANCERS BY ENVIRONMENTAL AND OCCUPATIONAL STRESSORS. Szmigielski, S.; Bielec, M.; Janiak, M. (Center Radiobiology and Radioprotection, 128 Szaserow, 00909 Warsaw, Poland).

The influence of environmental and occupational stressors (crowding, isolation, light and noise, and moderate hypo- and hyperthermia) combined with ionizing and nonionizing microwave radiation on the development and growth of experimental skin and breast cancers will be investigated in mice. Skin cancer will be induced in mice by painting with 3,4-benzopyrene, and breast cancer will be studied in C3H mice with a high incidence of spontaneous breast cancer. 3,4-Benzopyrene treatment will be applied at different periods prior to or simultaneously with stressor exposure or in combination with radiation. Time of tumor development, survival, and natural antineoplastic resistance (cancer lung colony test and natural killer activity) in animals exposed for different periods to the stressors will also be evaluated. (funding period 0/80-10/85)

Supporting Agency:Ministry Natl. Defense, Poland

0578 DRUG LOCALIZATION BY HYPERTHERMIA AND LIPOSOMES. Magin, R. L.; Weinstein, J. N.; Cysyk, R. L.; Zaharko, D. S. (Dept. Electrical Engineering, Sch. Engineering, Univ. Illinois, Urbana Champaign Campus, 207 Engineering Hall, Urbana, IL 61801).

Local tumor hyperthermia with microwaves (2,450 MHz) is being tried to increase the effectiveness of solid tumor chemotherapy by localization of drug delivery to the region of the tumor. Specially formulated heat-sensitive liposomes that predominantly release their contents in anatomical regions of local hyperthermia will be used. The local tumor hyperthermia (42 C, 60 min) will be produced either by microwaves or by submersion in a temperature-controlled water bath. The effect of combined local hyperthermia and heat-sensitive liposome treatments on the growth of solid Lewis lung and L1210 tumors will be studied. To date enhanced accumulation of ^3H-methotrexate from heat-

sensitive liposomes into locally heated tumors has been demonstrated. A 4.3:1 ratio of drug uptake between heated and contralateral nonheated Lewis lung tumors (microwave heating) and 14:1 for L1210 tumors (water bath heating) were observed. Preliminary in vivo studies at a therapeutic dose of methotrexate (3 mg/kg, intraveneously, 1x on days 1-3) indicated longer tumor growth delays following treatment with local hyperthermia and heat-sensitive liposomes containing methotrexate than either for heat alone or for the equivalent dose of free methotrexate and heat. (funding period 0/80-3/80)

Supporting Agency:HEW, PHS, NIH, Div. Res. Resources

0579 MICROWAVE METHODS OF LUNG WATER MEASUREMENT. Durney, C. H.; Bragg, D. G.; Iskander, M. F.; Stephen, R. (Dept. Radiology, Sch. Medicine, Utah Higher Education System, Univ. Utah, 1400 E. 2nd St., Salt Lake City, UT 84112).

Experience with a noninvasive microwave transmission phase measurement technique to continuously monitor small changes in lung water content is extended to practical clinical use. The amount of microwave phase change produced by a given change of lung water will be quantified by a previously developed computer program. Microwave measurements will be made simultaneously with computed axial tomographic scans as pulmonary edema is induced in dogs. These data will be used in the computer program to refine the calculations and furnish the best possible methods for identifying changes in lung water from microwave measurements. Microwave measurements will then be made on renal failure patients and physically normal, schizophrenic patients during dialysis and hemofiltration. This procedure will provide an excellent human model of pulmonary edema, since the impact of removal and addition of varying amounts of fluid under closely controlled, clinically supervised conditions can be evaluated. The expected result of the proposed work is a compact, portable, practical, and noninvasive microwave method for clinically monitoring small changes in total lung water content. (funding period 12/77-11/80)

Supporting Agency:HEW, PHS, NIH, Natl. Heart, Lung, and Blood Inst.

0580 OSTEOGENESIS IMPERFECTA TREATED WITH ELECTRIC FIELD. Albright, J. A.; Saha, S.; Gillespie, T. E. (Dept. Orthopedics, Sch. Medicine, Louisiana State Univ., Shreveport Campus, Shreveport, LA 71105).

The effect of an electromagnetic field on disuse osteoporosis in larger animals is being investigated to determine if proper manipulation of bioelectric phenomena is useful for treating patients with osteogenesis imperfecta or idiopathic or senile osteoporosis. In addition, the effect of such treatment on epiphyseal growth will be evaluated. In vivo studies will include evaluation of cortical bone using x-rays, evaluation of trabecular bone using computerized axial tomography, measurement of stress wave propagation through the intact bone using a previously designed noninvasive electromagnetic device as an index of the material properties of both cortical and trabecular bone, and microscopic evaluation of the cellular response in bone. A pilot project to treat a small number of patients with osteogenesis imperfecta will be initiated during the second year of the study and the results will be evaluated using the in vivo techniques described above. Assuming that the results appear promising and that no adverse effects are encountered, the treatment program will be extended to additional numbers of patients. (funding period 8/79-7/80)

Supporting Agency:HEW, PHS, NIH, NIAMDD

0581 A NEW METHOD TO MEASURE THE RATE OF FRACTURE HEALING. Saha, S.; Albright, J. A.; Gillespie, T. E.; Reddy, G. N. (Dept. Orthopedics, Sch. Medicine, Louisiana State Univ., Shreveport Campus, Shreveport, LA 71105).

A noncontacting and noninvasive electromagnetic device that measures the rate of fracture healing has been developed and is being tested. The device can detect the propagation of stress waves in a bone in a manner independent of the mechanical properties of the soft tissue; it monitors the magnetic field produced by the piezoelectric charge associated with a stress wave propagating along a long bone. The stress wave is generated in embalmed human femora and the device is used to monitor the stress waves at two points along the length of the bone. After initial wave propagation studies were completed, simulated fractures were experimentally induced in the samples by making serial cuts of increasing depth into the bone cortex. The wave propagation studies were then repeated on each sample. A preliminary result of this study indicates that the changing characteristics of the stress wave as it propagates along the bone may be correlated to the degree of union at the point of simulated fracture. The sensitivity of this piezoelectric device will be improved so that it may be used clinically without a signal averager. This device will be used to measure the rate of fracture healing in experimental animals and the results will be compared with the strength of healing bone. (funding period 7/79-6/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Arthritis, Metabolism, and Digestive Diseases

0582 ELECTROMAGNETIC BLOOD THAWING. Rasmussen, W. T.; Bentley, K. (Command Control E.W. Systems and Technology Dept., Naval Ocean Systems Center, Navy, U.S. Dept. Defense, San Diego, CA 92152).

The feasibility of using electromagnetic energy (EM) to thaw frozen blood products for clinical

use in the Navy will be determined. Properly matched dielectric materials will be used in the antenna or waveguide to achieve uniform heating, as a major complication of EM heating is thawing uniformity. The feasibility of EM thawing will first be examined with small aliquots of frozen RBC. Work will then progress to thawing actual sized units of blood. (funding period 10/76-10/81)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command

0583 INFLUENCE OF MICROWAVES ON DAILY PROBLEM SOLVING BY MONKEYS. de Lorge, J. O.; Knepton, J. (Medical Sciences Dept., Naval Aerospace Medical Res. Lab., Navy, U.S. Dept. Defense, Pensacola, FL 32508).

The ability of primates to learn a complex task while they are being irradiated with microwaves will be investigated. In addition, the minimum power level required to temporarily disrupt learning ability will be determined. The results of these experiments will be correlated with behavior data from another project to predict the minimum level necessary to affect learning in humans. Monkeys will be trained to respond on a task that requires the animal to learn a sequence of stimulus-response combinations. Each stimulus presentation will be associated with a specific series of responses. A correct response sequence will result in food reinforcement. The correct stimulus-response sequence will be changed for each experimental session so that the task must be relearned daily. Eventually a stable learning curve will evolve; it will serve as a baseline on which the effects of microwaves will be observed. The monkeys will be exposed to 3-μsec pulses of 1.27 GHz irradiation of 330 pulses/sec for 30-min periods, with power densities from 0-30 MW/cm^2 as measured in the far field. Exposures at 5.62 GHz will also be explored. (funding period 10/78-10/81)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0584 THE INFLUENCE OF CHRONIC EXPOSURE TO LOW LEVEL PULSED MICROWAVES ON PERFORMANCE AND COGNITIVE BEHAVIOR. Lebovitz, R. M. (Dept. Physiology, Southwestern Medical Sch., Health Science Center at Dallas, Univ. Texas, 5323 Harry Hines Blvd., Dallas, TX 75230).

The risks inherent in chronic exposure to low level, pulsed microwaves will be defined with the aim of providing a quantitative justification for future safety standards. Variations in the performance of complex behavior tasks (bar press, repeated acquisition of task, time estimation, and differential response) will be assessed concomitant with long-term exposure to 1.3 GHz microwaves. Average specific dose rates will range from 0.5 to 30 mW/g. The animals will be exposed in circular waveguides and will be free moving with one animal per cage. Thirty-two animals (16 exposed and 16 controls) will be used in each part of the study. Dose/response curves will be derived and an effort will be made to distinguish whether behavioral alterations are due to induced heat or to the microwave field. The effect of microwaves on the action of certain drugs will also be studied. (funding period 7/79-n/a)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0585 RADIO FREQUENCY/MICROWAVE EFFECTS UPON THE CENTRAL NERVOUS SYSTEM. Shelton, W. W. (Graduate Sch., Florida Inst. Technology, Country Club Rd., Melbourne, FL 32901).

The influence of microwaves on neuronal excitability will be determined by assessing calcium ion efflux in irradiated rat brain. A two phase experimental approach is proposed. In the first phase, rats will be administered radioactive calcium and the uptake kinetics in the forebrain will be determined. The interval required for the calcium ions to reach a plateau will be the postinjection time prior to initiation of irradiation. In the second phase, rats treated with radioactive calcium will be irradiated or sham-irradiated (control) in the far-field microwave region for 20 min. Several irradiation schemes comprised of various combinations of power densities and carrier frequencies of current interest will be used. The calcium efflux in both irradiated and control brains will be determined by liquid scintillation counting. Differences will be tested for statistical significance. Data obtained from these experiments will enable more accurate reappraisal of Air Force and occupational personnel exposure standards for microwave radiation. (funding period 6/79-4/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Office Scientific Res., Bolling Air Force Base

0586 NAVY ENVIRONMENT: EVALUATION OF THE POTENTIAL NEUROLOGICAL HAZARDS OF MICROWAVE FIELDS. Partlow, L. M.; Stensaas, L. J. (Dept. Pharmacology, Sch. Medicine, Univ. Utah, Utah Higher Education System, 1400 E. 2nd St., Salt Lake City, UT 84112).

The effects of low level, nonthermal electromagnetic fields on various parameters of the brain will be investigated to determine if such low level fields can affect brain function or the general properties of nerve tissue. Tissues will be exposed to at least five different power levels at frequencies of 600 MHz and 2,450 MHz. A new biochemical technique that employs 2-deoxyglucose will be used to quantitate regional brain activity in conjunction with a quantitative method using the marker enzyme, peroxidase, to determine regional blood-brain barrier permeability. Penetrability will be assessed by means of fluorescein. Localized regions that appear to have been affected by the microwave ir-

radiation will be further evaluated by transmission electron microscopy for ultrastructural changes. (funding period 9/78-n/a)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0587 NONLINEAR INTERACTIONS OF ELECTROMAGNETIC WAVES BIOLOGIC. Barnes, F. S.; Gamow, R. I. (Dept. Electrical Engineering, Sch. Engineering and Applied Science, Univ. Colorado, Boulder Campus, 1200 University Ave., Boulder, CO 80302).

Measurements will be made on the change of firing frequencies of the ganglion cells of the aplysia as a function of microwave poser density, temperature, and other parameters. In addition, the presence of shifts in the direct current potential and the characteristic impedance for *Phycomuces* on exposure to microwave power will be investigated. The investigations will extend to the nonlinear characteristics of biologic fluids in order to analyze high-field effects and to understand the nature of membranes when subjected to radio and microwave frequencies. (funding period 9/78-8/80)

Supporting Agency:HEW, PHS, FDA

0588 RADIOFREQUENCY RADIATION EFFECTS ON EXCITABLE TISSUES. Burdette, E. C. (Systems and Techniques Lab., Engineering Experiment Station, Georgia Inst. Technology, 225 North Ave., NW, Atlanta, GA 30332).

The effects of pulsed microwave radiation on the normal physiologic functions of cardiac cell aggregates will be investigated. Data obtained from the experiments will enable more accurate reappraisal of Air Force and occupational personnel exposure standards for microwave radiation. An exposure system will be designed to provide proper dosimetry of electromagnetic radiation (EMR) for exposure of cardiac cell aggregates (CCA). Following dosimetry and thermal alteration studies, cardiac aggregate clusters will be exposed to both continuous wave and at least four pulsed-wave EMR conditions using an exposure frequency of 2,450 MHz and two absorbed power levels. The effect of EMR on CCAs will be evaluated using the following parameters: beat rate, maximum diastolic potential, action potential duration, slope of pacemaker potential, maximum upstroke velocity, and threshold potential alterations. These cellular interactions are the initiating activity for macroscopic-level functions. The aggregates offer not only a sensitive system in which to study fundamental effects, but also a means by which these effects may be related to gross responses. (funding period 3/79-4/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Office Scientific Res., Bolling Air Force Base

0589 EFFECTS OF 2,450 MHz MICROWAVE RADIATION ON CULTURED HEART CELLS. Galvin, M. J.; McRee, D. I.; Lieberman, M. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

The effects and mechanisms of the interaction of 2,450 MHz microwave radiation with biologic tissue will be studied in cultured heart cells obtained from 8-day-old quails and maintained in culture for 2 days. In addition, the relationship between the amount of microwave energy absorbed and the effects will be analyzed. The temperature, humidity, and other factors will be carefully monitored to eliminate any effects not directly caused by microwave radiation. Experiments are planned for this new test system as soon as the experimental design is completed. (funding period 10/78-9/79)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0590 INFLUENCE OF 2,450 MHz MICROWAVE RADIATION ON CATS SUBJECTED TO MYOCARDIAL ISCHEMIA. Galvin, M. J.; McRee, D. I. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

The effects of 2,450 MHz microwave radiation on the course of myocardial ischemia are being examined in cats. Biochemical and physiologic parameters that are influenced by myocardial ischemia are being followed subsequent to myocardial ischemia. These include plasma and tissue creatinine phosphokinase levels, electrocardiogram changes and measurement of infarct size, cardiac output, and blood pressure. In conjunction with this, methods have been developed for determining the dose of microwave radiation absorbed by the myocardial tissue. Tissue temperature is being carefully monitored to determine the thermal contribution of microwaves to the ischemic injury. Results are not yet available. (funding period 10/78-9/79)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0591 RF EFFECTS OF IMMUNE SYSTEMS. Liburdy, R. P. (Sch. Aerospace Medicine, Air Force, U.S. Dept. Defense, Brooks Air Force Base, San Antonio, TX 78235).

The effects of electromagnetic radiation (EMR) stress on immune systems will be investigated specifically to determine the magnitude and direction, causes, and thresholds of EMR induced changes in immune responsivity. Nonpunitive thresholds for frequency and power dependency of continuous and pulsed wave EMR stress on immune function will also be established. Radio frequency-induced changes in the ability of test animals to mount a viable in vivo cell-mediated immune response (as demonstrated by cutaneous delayed hypersensitivity) to antigenic challenge will be quantitated. Sub-

sequently, studies to delineate thorough in vitro techniques for studying the effects of EMR stress on specific cell-mediated effector mechanisms operating in delayed hypersensitivity will be conducted. (funding period 1/76-9/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0592 NAVY ENVIRONMENT: NONIONIZING ELECTROMAGNETIC FIELD EFFECTS ON MUSCLE AND NERVE CELLS. Portela (Consejo Nacional de Investigaciones Cientificas y Tecnicas, Rivadavia 1917, Buenos Aires, Argentina).

The very sensitive intracellular mechanisms for response to electromagnetic energy (EME) will be studied to determine the mechanisms that are operative at the site of EME interaction with tissue. Nerve-muscle preparations from frogs, both in vitro and in vivo, will be used to define the effects and study the mechanisms of EME interactions at the cellular level with respect to electric, osmotic, and temperature parameters. Three specific regions will be studied: the motor end-plate region, the nerve terminal region (presynaptic membrane), and the cellular membrane region free of neuromuscular junction (conducting cell membrane component). Using mitochondria, studies will be made of the cellular indicators of the state of the cell energy metabolism related to the regulation of the adenosine triphosphate-adenosine diphosphate energy cources and associated mechanisms. In addition, oxygen consumption control and the distribution of sodium, potassium, and chloride ions will be studied. (funding period 6/78-n/a)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

0593 EFFECT OF EXPOSURE TO MICROWAVES ON THE NEUROENDOCRINE STATUS OF THE RAT. Stith, R. D. (Dept. Physiology and Biophysics, Sch. Medicine, Health Science Center, Univ. Oklahoma, Box 26901, Oklahoma City, OK 73190).

Rats will be exposed to whole-body continuous wave or pulsed wave microwave radiation to determine if the exposure results in quantifiable alterations in the neuroendocrine status of the brain. Rats will be exposed to various power densities of microwaves and then hypothalamic and brain stem slices will be assayed for norepinephrine, dopamine, serotonin, cyclic adenosine monophosphate, cyclic guanosine monophosphate, tyrosine hydroxylase, and tryptophan hydroxylase. In addition, blood samples will be assayed for the pituitary hormones--adrenocorticotropic hormone, growth hormone, and thyroid-stimulating hormone. Data obtained from these experiments will enable more accurate reappraisal of Air Force and occupational personnel exposure standards for microwave radiation. (funding period 1/79-2/80)

Supporting Agency:U.S. Dept. Defense: Air Force, Office Scientific Res., Bolling Air Force Base

0594 TISSUE INTERACTIONS WITH NONIONIZING ELECTROMAGNETIC FIELDS. Adey, W. R.; Bawin, S. M.; Sheppard, A. R.; Sagan, P. M.; Liu, S. L. (Dept. Medicine and Surgery, Medical Center, VA, 11201 Benton St., Loma Linda, CA 92357).

The behavioral and neurochemical effects produced by tissue interactions with weak (≤ 3 mW/cm^2) electromagnetic fields (450 MHz), amplitude modulated at brain rhythm frequencies (0-30 Hz), are being studied. The neurochemical effects of weak radio frequency radiation on ionic binding in brain tissue are being investigated on the awake, intact cat cortex. Twenty animals have been studied so far, including nonirradiated controls. The results indicate an increase in the release of previously bound calcium during the irradiation period (60 min). Internal field strength will be measured with an anisotropic implantable probe provided by the BRH. Comparative studies in isolated brain tissue have also been started. Behavior studies include monitoring the performance of eight chicks exposed to 450 MHz fields (1 mW/cm^2, modulated at 16 and 3 Hz) that were tested on the same fixed time schedule of reinforcement as was carried out at the University of California (Los Angeles) to confirm the successful transfer of the behavioral procedure and apparatus. The data will be analyzed on the PDP 11/70 computer. Further investigations will be dictated by the outcome of the completed behavioral data analysis. Mechanisms for the transduction of extracellular weak low frequency electric signals in brain tissue have been further studied in terms of the structural and energetic requirements of cell membranes. This complex transduction is discussed in terms of possible tunneling of ions along the potential energy surface of the membrane. (funding period 10/78-n/a)

Supporting Agency:VA, Dept. Medicine and Surgery

0595 PHYSIOLOGICAL EFFECTS OF ELECTRIC FIELDS IN ANIMALS. Michaelson, S. (Dept. Radiation Biology and Biophysics, Sch. Medicine and Dentistry, Univ. Rochester, 601 Elmwood Ave., Rochester, NY 14627).

Studies are being performed in the rat and dog to relate the sequential changes in hypothalamic and pituitary functions to alterations in body metabolism or homokinetic perturbations as a result of exposure to various regimens of x-rays, microwaves, or combinations of these two. The effects of exposure are being studied in perinatal and adult animals. Radioimmunoassay and competitive protein-binding analysis are being utilized to assess pathophysiologic sequelae from exposure to electromagnetic radiant energies. Fluctuations in pituitary, thyroid, and adrenal hormones; homeostasis; impairment of physiologic capacity; and functional integrity of the neuroendocrine system are being measured. (funding period 0/79-n/a)

Supporting Agency:U.S. Dept. Energy, Office Health and Environmental Res.

0596 THE EFFECT OF 2,450 MHz MICROWAVE RADIATION ON MAST CELLS. Ortner, M. J.; Galvin, M. J. (Molecular Biophysics Section, Natl. Inst. Environmental Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

The effect of microwave radiation was studied on active secretory cells. Rat peritoneal mast cells were exposed to 2,450 MHz microwave radiation at specific absorption rates of 8.5 and 42.5 mW/ml for periods of up to 3 hr. Cells were maintained throughout exposure at 37 C. There was no effect on cell viability or spontaneous histamine release. Mast cells exposed to compound 48/80 after prior irradiation or during simultaneous irradiation secreted histamine in a manner similar to unexposed cells. (funding period 10/78-9/79)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0597 ELECTROMAGNETIC RADIATION AND BIOLOGICAL SYSTEMS. Adey, W. R.; Bawin, S. M.; Sheppard, A. R.; Sagan, P. M. (Dept. Medicine and Surgery, Medical Center, VA, 11201 Benton St., Loma Linda, CA 92357).

The biologic effects on cell membrane surfaces, behavior, and neurophysiology of electromagnetic fields at extra-low and radio frequencies are being studied. The effects on molecular biology of cell membrane surfaces are being studied in samples of rat synaptosomes (routine prepared in the laboratory) that have been exposed during perfusion with a physiologic saline solution (30 min) to 450 MHz fields (≤ 3 mW/cm^2), amplitude modulated at 16 Hz. The results collected to date suggest that calcium release from exposed synaptosomes differs from nonexposed control samples. The effects of electromagnetic fields on behavior are being studied by placing two monkeys in isolation chambers that have been designed and built for testing and recording restrained monkeys. The animals now in training are on a Differential Reinforcement Schedule of Low Rates for Responding (5 msec)--Limited Hold (2.5 msec). The animals will be exposed to 60 Hz fields with gradients in air up to 1,000 V/m. A PDP 11/70 computer and six terminals have been installed in the Research Service, and programs are being developed for acquisition and analysis of data. Neurophysiology studies include: (A) aplysia nerve cell responses to low frequency electric fields imposed either extra- or intracellularly. Response to extracellular current (densities ($\leq 10^{-4}$ A/cm^2), by comparison with more regular responses produced by intracellular current injection, suggests interaction among synaptically coupled cells within the ganglion. These electric field data will be compared with data acquired with low frequency magnetic fields. (B) Electrophysiologic activity of rat hippocampal slices (450 μm thick), bathed in oxygenated physiologic solution, will be analyzed following electrical stimulation of specific fiber pathways and stimulation of the whole slice, via application of an electric field in the bathing fluid. Visualization of extracellular calcium binding is now being attempted with fluorescent microscopy, using chloratetracycline as the fluorescent agent and lanthanum as a transmembrane calcium movement inhibitor. (funding period 10/78-n/a)

Supporting Agency:VA, Dept. Medicine and Surgery

0598 STUDIES OF MICROWAVE RADIATION AS A TOOL IN SOIL STERILIZATION AGAINST MAJOR DISEASES AND PESTS OF AGRICULTURAL CROPS. Wutoh, J. G. (Dept. Biology, Univ. Maryland Eastern Shore Undergraduate Sch., Princess Anne, MD 21853).

Soil samples from different soil types and locations are being analyzed for soil microorganisms and arthropods before and after exposure to 2,450 MHz, 60 KW fully-conveyorized microwave source. The effect of the microwave radiation on the soil organisms is being assessed using the classical microbiologic method and the Dry-Funnel method for extraction of small arthropods developed by K. E. Fletcher of the Rothamsted Experiment Station at Harpenden, England. Results to date indicate that all fungi were detected after treatment; all bacteria except spore-forming types were killed; all nitrogen-fixing bacteria were inactivated and killed; no nematodes survived the microwave treatment; and all isolated arthropods (eggs, larvae, and adults) were killed by the microwave treatment. There did not appear to be any residual effects of the microwaves. The effect of the microwaves on the soil organisms was nonselective. There appeared to be a correlation between moisture loss and increase in soil temperature and the mortality of the organisms. Seed germination and growth of soybeans were excellent in soil after a 6-min soil exposure but both germination and growth were retarded after a 10-min soil exposure. The effect of microwaves was probably due to a change in soil structure and compactability caused by breakdown of organic matter. (funding period 3/76-8/79)

Supporting Agency:U.S. Natl. Aeronautics and Space Admin., Wallops Flight Center

0599 INVESTIGATION OF EFFECTS OF MICROWAVES ON GROWTH OF *ASPERGILLUS FLAVUS* ON CORN. Albano, M. (Dept. Natural Sciences, Univ. Maryland Eastern Shore Undergraduate Sch., Princess Anne, MD 21853).

The effect of microwaves on the growth of *Aspergillus flavus* on corn in storage is being investigated. Preliminary studies have shown that drying corn by microwaves does not adversely affect the nutritional value of corn. Seed germination does not seem to be adversely affected either. Corn samples both freshly harvested and dried were exposed to different doses of microwaves. Microwaves were generated on a commercially available microwave oven. At 420 W, exposures of 60 and 90 sec showed inhibitory effect; however, with a 180-sec exposure, no inhibition was observed. The

next phase of the project will involve the investigation of the effect of microwaves on aflatoxin produced by *A. flavus*. The usefulness of microwaves for drying corn may be determined by any modifying effect that microwaves may have on aflatoxin chemical structure or toxicity. (funding period 6/79-6/80)

Supporting Agency:U.S. Natl. Aeronautics and Space Admin., Wallops Flight Center

0600 EFFECTS OF LONG-TERM LOW-LEVEL RFR EXPOSURE ON RATS. Guy, A. W.; Chow, C. K. (Dept. Rehabilitation Medicine, Sch. Medicine, Univ. Washington, 500 17th Ave., Seattle, WA 98122).

No descriptive information is available. (funding period 9/78-8/83)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0601 RECEPTORS MEDIATING EFFECTS OF MICROWAVE RADIATION. Wilson, B. (Research Triangle Inst., P.O. Box 12194, Research Triangle Park, NC 27709).

No descriptive information is available. (funding period 6/79-5/81)

Supporing Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0602 FOCAL MICROWAVE RADIATION THERAPY--PRECLINICAL EVALUATION. Samaras, G. M. (Dept. Radiology, Sch. Medicine, Baltimore Professional Sch., University Maryland, 1420 N. Charles St., Baltimore, MD 21201).

No descriptive information is available. (funding period 9/79-8/80)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Neurological and Communicative Diseases and Stroke

Funding Period Modifications:

0603 LASER EYE MEASUREMENT AND EVALUATION SYSTEM. Brucker, A. P.; Auth, D. C. (Dept. Aeronautics and Astronautics, Sch. Engineering, Univ. Washington, 206 Guggenheim Hall, Seattle, WA 98105).

Funding period extended to 11/79. See Current Research 0479 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0604 LOCALIZED ELECTROMAGNETIC HEATING. Jones, R. C. (Dept. Radiology, Sch. Medicine, Univ. Arizona, 1501 N. Campbell Ave., Tucson, AZ 85721).

Funding period extended to 6/80. See Current Research 0481 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Cancer Inst.

0605 MICROWAVE EXPOSURE SYSTEMS AND MICROWAVE DOSIMETRY. McRee, D. I. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Funding period 10-76-9/79. See Current Research 0516 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0606 RADIOFREQUENCY RADIATION MECHANISMS. Smith, G. (Dept. Electrical Engineering, Sch. Engineering, Georgia Inst. Technology, 225 North Avenue, NW, Atlanta, GA 30332).

Funding period limited to 10/79. See Current Research 0477 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0607 MICROWAVE EFFECTS. Tredici, T. J. (Sch. Aerospace Medicine, Air Force, U.S. Dept. Defense, Brooks Air Force Base, San Antonio, TX 78235).

Funding period extended to 9/82. See Current Research 0488 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0608 TUMOR RADIOCHEMOTHERAPY--EFFECTS OF ULTRASOUND AND HEAT. Hahn, G. M. (Dept. Radiology, Sch. Medicine, Standford Univ., Standford, CA 94305).

Funding period extended to 3/80. See Current Research 0443 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Cancer Inst.

0609 EFFECTS OF ACUTE ELECTROMAGNETIC RADIATION ON THE CENTRAL NERVOUS SYSTEM: MORPHOLOGICAL STUDY OF HYPOTHALAMIC AND SUBTHALAMIC REGIONS. McKee, A. E.; Dorsey, C. H. (Experimental

Pathology Dept., Naval Medical Res. Inst., Navy, U.S. Dept. Defense, Bethesda, MD 20014).

Funding period extended to 9/80. See Current Research 0347 for description of this project.

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0610 EFFECTS OF MICROWAVES ON NEURAL RESPONSE. McRee, D. I.; Wachtel, H. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, DEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Funding period 10/76-9/79. See Current Research 0512 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0611 USE OF SYNAPTOSOMES AS AN EXPERIMENTAL MODEL FOR EVALUATING THE EFFECT OF ELECTROMAGNETIC RADIATION (EMR) ON NEURAL MEMBRANE FUNCTIONS. Millar, D. B.; Christopher, J. P. (Biochemistry Div., Naval Medical Res. Inst., Navy, U.S. Dept. Defense, Bethesda, MD 20014).

Funding period extended to 9/83. See Curren Research 0490 for description of this project.

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0612 RFR EFFECTS ON GI TRACT. Erwin, D. N. (Sch. Aerospace Medicine, Air Force, U.S. Dept. Defense, Brooks Air Force Base, San Antonio, TX 78235).

Funding period extended to 12/80. See Current Research 0397 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0613 EFFECTS OF 2,450 MHz MICROWAVES ON EMBRYONIC DEVELOPMENT, IMMUNOLOGY, AND FERTILITY. McRee, D. I.; Galvin, M. J.; Thaxton, J. P.; Parkhurst, C. R. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Funding period 10/76-9/79. See Current Research 0501 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0614 THE EFFECT OF MICROWAVE RADIATION ON THE HEART OF EMBRYONIC QUAIL. Hamrick, P. E.; McRee, D. I. (Nonionizing Radiation Work Group, Natl. Inst. Environmental Health Sciences, NIH, PHS, HEW, P.O. Box 12233, Research Triangle Park, NC 27709).

Funding period extended to 9/79. See Current Research 0445 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Environmental Health Sciences

0615 NEUROENDOCRINE EFFECTS OF PULSED MICROWAVE RADIATION. Lotz, W. G.; O'Neill, T. P. (Medical Sciences Dept., Naval Aerospace Medical Res. Lab., Navy, U.S. Dept. Defense, Pensacola, FL 32508).

Funding period extended to 10/82. See Current Research 0483 for description of this project.

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0616 BIOLOGIC CONSEQUENCES OF PULSED VERSUS CONTINUOUS WAVE RADIOFREQUENCY RADIATION (RFR). Cain, F. (Georgia Technical Res. Inst., Atlanta, GA 30332).

Funding period extended to 11/79. See Current Research 0530 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

0617 BIOLOGICAL CONSEQUENCES OF PULSED VERSUS CONTINUOUS WAVE RADIOFREQUENCY RADIATION (RFR). Chou, C.; Choo, C. K. (Dept. Rehabilitation Medicine, Sch. Medicine, Univ. Washington, 500 17th Ave., Seattle, WA 98122).

Funding period extended to 12/79. See Current Research 0530 for description of this project.

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine

6497 **OPENING REMARKS.** *(Eng)* Simon, N. (Mount Sinai Sch. Medicine, City Univ. New York, New York, NY). *Bull NY Acad Medicine* 55(11): 973-975; 1979 (no refs).

The Subcommittee on Public Health Aspects of Energy of the New York Academy of Medicine sponsored a conference on the biologic effects of microwaves as part of a series of conferences to educate physicians as to the state of the art of the biologic effects of various energy sources on man. Microwaves are an urgent issue because of the conflict over the establishment of appropriate guidelines for exposure standards for the public.

6498 **SOURCES AND BASIC CHARACTERISTICS OF MICROWAVE/RF RADIATION.** *(Eng)* Osepchuk, J. M. (Res. Div. Library, Raytheon Company, 28 Seyon St., Waltham, MA 02154). *Bull NY Acad Med* 55(11): 976-998; 1979 (8 refs).

Sources and basic characteristics, including electrical concepts and physical aspects, of microwave radiation (10 MHz to 100 GHz) are reviewed. The microwave portion of the spectrum has generated considerable interest because of its penetrating quality in man and animals. Topics discussed include: dielectric properties of foods and other materials at 2,450 MHz, power density and radiation fields, the relation of radiated power to power flux, the present state of the art in the generation of microwave power, applications of microwave and radio frequency (RF) power, means of reducing exposure to microwave/RF power, the relation of emission to exposure, and a comparison of man-made and natural levels of nonionizing radiation. The basic radiation pattern is reviewed to provide some gauge of likely exposure levels for a given power, frequency, and antenna type. In addition, the meaning of emission and exposure levels are distinguished as well as the relevance of the susceptibility of medical electronics to potentially hazardous interference.

6499 **DOSIMETRY–THE ABSORPTION PROPERTIES OF MAN AND EXPERIMENTAL ANIMALS.** *(Eng)* Gandhi, O. P. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). *Bull NY Acad Med* 55(11): 999-1020; 1979 (29 refs).

Current knowledge of electromagnetic absorption by man and animals in the frequency range of 10 MHz-10 GHz is reviewed. The techniques for studying electromagnetic absorption include carefully proportioned, reduced scale models; experiments on small animals; prolate spheroidal, ellipsoidal, and cylindrical models; moment-method solutions; and multilayered models of man. Whole-body absorption in free-space irradiation, the most commonly studied condition, is dependent on the orientation of the electric field relative to the longest dimension of the body. The effect of intermediate angles of body orientation and resonance conditions on the distribution of power deposition are also discussed. It is concluded that densitometry is not of primary importance and that for a given power density, the absorbed dose can vary by orders of magnitude depending on such variables as the frequency of radiation, size and orientation of the animal (e.g., head resonance and multi-animal effects), and the physical environment (e.g., ground and reflector effects). Information is lacking for realistic conditions of exposure such as the effects of finite size, finite conductivity, ground, and reflectors as well as for the problem of near-field and partial-body exposures encountered by operators of electromagnetic radiation equipment.

6500 **RADIATION SURVEYS–MEASUREMENT OF LEAKAGE EMISSIONS AND POTENTIAL EXPOSURE FIELDS.** *(Eng)* Janes, D. E. (Office Radiation Programs, EPA, Silver Spring, MD). *Bull NY Acad Med* 55(11): 1021-1041; 1979 (66 refs).

Results of measurements of radio frequency (3 kHz-300 GHz) electromagnetic fields from a number of different sources are presented. It is found that the multisource, multifrequency, general radio frequency environment is dominated by low-level radio and television transmission. Microwave radio relays, low-power radars, mobile communications systems, and microwave ovens make almost negligible contributions to the general radio frequency environment. The largest multisource radar field measured in the general environment of one urban area was less than the median value for the broadcast band (54-900 MHz). It is estimated that most of the population (over 99%) is continuously exposed to levels $<1\ \mu W/cm^2$. This level is well below the current American National Standards Institute standard of $10{,}000\ \mu W/cm^2$ and is below the extremely conservative Russian standards of $1\ \mu W/cm^2$ for frequencies between 30 and 300 MHz and $5\ \mu W/cm^2$ for frequencies between 300 MHz and 300 GHz. The specific source environment for most broadcast sources is below $100\ \mu W/cm^2$. The only fields in excess of this value occur on the antenna towers, in the immediate vicinity of the base of some frequency modulated (FM) antenna towers, and on the roofs of tall buildings that are located within a city block or so of FM and television broadcast antennas. When considering other high power sources such as radar and satellite communications systems, the potential for exposure to obviously high levels of radiation ($\geq 10{,}000\ \mu W/cm^2$) is small. However, the population exposed to specific source environments $>1\ \mu W/cm^2$ remains to be determined. Intermittent, partial body exposures to high levels of radiation do occur, and their occurrence confounds the interpretation of the impact of near-field exposures. Leakage fields from medical diathermy units, electrosurgical units, industrial sources, and the fields very near to the antennas of

mobile communications equipment have been measured to be in excess of 200 V/m and 0.5 A/m, i e., the electric and magnetic field equivalents of a far-field power density of 10,000 $\mu W/cm^2$. Better knowledge of the rates and sites of energy deposition is needed before near-field exposures can be meaningfully compared to the far-field exposure data that form the basis for current standards.

6501 GENERAL DISCUSSION: SESSION I. *(Eng)* Osepchuk, J. M. (Res. Div., Raytheon Co., Waltham, MA); Gandhi, O. P.; Janes, D E. *Bull NY Acad Med* 55(11): 1042-1046; 1979 (no refs).

A general discussion relating to human exposure to radio frequency and microwave radiation is presented. Topics discussed include: the reliability of commercial devices for detecting leakage from microwave ovens, patterns of leakage from microwave ovens and hospital microwave diathermy applicators, measurements of the general radio frequency environment in 15 cities in the United States, reflector effects and near-field noncontact situations, and natural sources of microwave and radio frequency radiation.

6502 BIOMEDICAL EFFECTS OF MICROWAVE RADIATION. *(Eng)* Wilkening, G. M. (Environmental Health and Safety, Bell Lab., Murray Hill, NJ) *Bull NY Acad Med* 55(11): 1047; 1979 (no refs).

In a brief presentation, it is contended that an important result of present knowledge about the biomedical effects of microwave radiation is the realization that the usefulness of most studies published more than a decade ago is open to serious question. Many earlier studies attempted to correlate exposure levels with observed biologic effects, and it was customary to express environmental levels of radiation in terms of average power density or equivalent far-field average power density with little attention to the specification of waveform, polarization, reflections, scattering, geometry of the body being irradiated, and whether exposure conditions are in the near- or far-field of the radiating source. It is suggested that specification of exposure levels without some qualification pertaining to these factors should be considered an obsolete practice.

6503 OCULAR EFFECTS OF MICROWAVE RADIATION. *(Eng)* Carpenter, R. L. (BRH, FDA, Winchester, MA). *Bull NY Acad Med* 55(11): 1048-1057; 1979 (20 refs).

Ocular effects of microwave radiation are discussed, with particular reference to experiments with the rabbit eye Studies involving the exposure of New Zealand white rabbits to 2.45-GHz radiation have shown that an incident power density of 250 mW/cm^2 acting on the eye for 35-40 min is required for cataract induction by a single exposure. Multiple exposures at 180 mW/cm^2 for 1 hr/day for 20 consecutive days were also cataractogenic. The earliest identifiable effect of microwaves on the eye occurred within 18 hr, with a greater than 20% decrease in the ascorbic acid concentration in the lens being noted. Radioautography has demonstrated that a single cataractogenic exposure inhibits DNA synthesis and mitosis in lens epithelial cells; recovery does not begin until the 5th day postirradiation and takes 10-14 days. Histopathologic studies of microwave cataract development in the rabbit eye revealed that the primary change occurs in the lens epithelium. Irradiated epithelial cells at the lens equator migrate posteriorly under the capsule, meanwhile undergoing mitotic cell division, so that a posterior epithelial layer becomes aberrantly formed. Large spherical or ovoid balloon cells appear around the 6th day at the equator and in the posterior subcapsular cortex. In many cells small vesicles accumulate and coalesce to form cystic cells that may unite with others and form larger cystic spaces. Measurement of the thickness of the posterior capsule revealed no significant differences between irradiated and nonirradiated lenses.

6504 BEHAVIORAL AND PSYCHOLOGICAL EFFECTS OF MICROWAVE RADIATION. *(Eng)* Justesen, D. R. (Res. Service, 151-L, VA Medical Center, 4801 Linwood Blvd., Kansas City, MO 64128). *Bull NY Acad Med* 55(11): 1058-1078; 1979 (40 refs).

Confirmed, indeterminate, and imaginary behavioral and psychologic effects of microwave radiation are reviewed. More than 5,000 reports of biologic effects have appeared in the literature of radio frequency radiations, with most being based on experimental exposures of small animals to fields in the microwave spectrum (300 MHz-300 GHz) or at lower radio frequencies; a substantial number relate in whole or in part to behavioral reactions. Most of the scientific reports from the United States are based on studies in which exposures were of short duration (minutes to hours) to highly intense fields well in excess of 10 mW/cm^2. Hard behavioral data that have emerged are associated with acute effects and include (in approximate order of decreasing field strengths): convulsive activity, work stoppage, work decrement, decreased endurance, perception of the field, and aversive behavior. Dose response studies in the laboratory indicate an absence of damaging effects of acute exposures (typically less than 60 min) at whole-body energy dose rates below 3 mW/g. This dose rate corresponds to an incident power density of radiation as low as 2-3 mW/cm^2 for small animals and 15-20 mW/cm^2 for human beings. A second category of behavioral reactions involves behavioral sequelae of indeterminate origin observed during

epidemiologic studies of industrial and military populations. An example of such sequelae is the neurasthenic syndrome, a reversible syndrome akin to mild depression. The syndrome has been attributed to weak microwave fields, but an etiologic connection has yet to be demonstrated or refuted. A third category of behavioral reactions to microwaves is that of imagined effects at power densities below the human body's rate of emitting microwave energy. Examples cited are the belief that video-display terminals emit significant quantities of microwave energy and the thesis that airline pilots have a higher than normal probability of fathering mongoloid children because of excessive exposure to microwaves.

6505 NEUROPHYSIOLOGIC EFFECTS OF RADIOFREQUENCY AND MICROWAVE RADIATION. *(Eng)* Adey, W. R. (ACOS/Res., 151, VA Hosp., 11201 Benton St., Loma Linda, CA 92357). *Bull NY Acad Med* 55(11): 1079-1093; 1979 (17 refs).

Evidence for interactions between radio frequency and microwave fields and brain tissue is reviewed. Two of the topics discussed are the possible anatomical and physiologic substrates for field interactions with brain tissue. Dendritic contacts in the brain are viewed as possible structural substrates for interaction with electromagnetic fields. The transactional processes of the neurons involve slow waves that, when transmitted from cell-to-cell, may leak into the cells' environment, suggesting that if the electroencephalogram has informational significance, then similar environmental fields may be able to induce subtle behavioral changes. The role of cell membrane surfaces in the detection of weak electromagnetic fields is also discussed; calcium ions appear to be the key to understanding cell surface transduction. Field interactions with brain tissue have been assessed by effects on calcium ion fluxes and the results of several experiments are reviewed. In summary, these studies disclosed a frequency window and an amplitude window, suggesting some form of quantum amplification. Chemical and physical models of interactive processes are briefly discussed, as are the emergent concerns on central nervous system sensitivities to nonionizing radio frequency radiation. The cooperative character of nonionizing radio frequency radiation and the central nervous system is demonstrated by the existence of windows in power and frequency. It is suggested that, by using nonionizing radio frequency radiation as a research tool, it may be possible to identify the intrinsic organization of brain tissue, the subtleties of neuroendocrine phenomena, and various immunologic reactions in terms of transductive coupling at the molecular level.

6506 HEMATOLOGIC AND IMMUNOLOGIC EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION. *(Eng)* Smialowicz, R. J. (Experimental Biology Div., Health Effects Res. Lab., MD-72, EPA, Environmental Res. Center, Research Triangle Park, NC 27711). *Bull NY Acad Med* 55(11): 1094-1118; 1979 (71 refs).

Clinical and epidemiologic human studies and experimental animal studies on the hematologic and immunologic effects of nonionizing electromagnetic radiation at frequencies ranging from 13.56 to 24,000 MHz and power densities ranging from <1 mW/cm^2 to 4,000 mW/cm^2 are reviewed. It is concluded that high intensity nonionizing electromagnetic fields induce thermal loads in animals that in turn affect the hematologic and immunologic systems. These responses are similar if not identical to responses elicited in animals following a stressful encounter or the administration of glucocorticoids. A more subtle type of induced heating may account for biologic effects reported in the absence of an increase in body-core temperature. These effects, similar to stress-type responses, may be attributed to the unique heating property of nonionizing electromagnetic radiation. It is not certainly known that these effects are necessarily the hallmark of changes in the hematologic or immunologic systems that will eventually lead to disease or to a more responsive immune system. Convincing evidence for a direct interaction of nonionizing electromagnetic radiation with hematopoietic cells in vitro or in vivo is not available. Clinical and epidemiologic studies are for the most part inadequate to assess effects on the hematologic and immunologic systems of humans exposed to nonionizing electromagnetic radiation.

6507 RECAPITULATION: BIOMEDICAL EFFECTS. *(Eng)* Cleary, S. F. (Dept. Biophysics, Virginia Commonwealth Univ., Richmond, VA). *Bull NY Acad Med* 55(11): 1119-1125; 1979 (22 refs).

Biologic effects of microwave radiation are reviewed. Cataract induction appears to be the only reported irreversible effect of accidental overexposure of human beings to microwave radiation, in spite of the degree of uncertainty surrounding exposure parameters. Microwave cataractogenesis has generally been assumed to be a consequence of excessive localized thermal stress due to exposure to high intensity (power densities >100 mW/cm^2) microwave fields. Field intensities of this magnitude produce convulsions and death from hyperpyrexia in experimental animals; although dose-effect relations are not completely determined, tissue thermal denaturation appears to be the mechanism for such effects. Uncertainty exists about the biomedical effects of microwave and radio frequency fields at intensities of ≤ 10 mW/cm^2 that result in minimal or undetectable levels of thermal stress. Representative of low-field intensity phenomena are microwave and radio frequency effects on the central nervous system and on the hematopoietic and im-

munologic systems. Although the mechanisms responsible for low intensity bioeffects are unknown, the data suggest involvement of nonuniform energy absorption within the bodies of animals or man that may result in microwave-specific thermal gradients and heating rates that depend on the wavelength and polarization of the field; the orientation, size, shape, and composition of the absorbing body; as well as the presence of reflecting surfaces. Without detailed information on the patterns of internal energy absorption and comparative thermal physiology, it is not feasible to extrapolate data from experimental animals to man.

6508 GENERAL DISCUSSION: SESSION II. *(Eng)* Wilkening, G. M. (Environmental Health and Safety, Bell Lab., Murray Hill, NJ); Adey, W. R.; Leach, W. M.; Justesen, D. R.; Cleary, S. F.; Simon, N.; Carpenter, R. L.; Smialowicz, R. J. *Bull NY Acad Med* 55(11): 1126-1132; 1979 (4 refs).

A general discussion session on the biologic effects of microwaves is presented. Topics discussed include: the effects of microwaves on brain function, the oncogenic potential of microwaves, the effects of microwaves on animal behavioral sensitivity to tranquilizers, and nonreversible effects of microwave exposure such as cataracts and convulsions or death due to hyperpyrexia.

6509 REVIEW OF SOVIET/EASTERN EUROPEAN RESEARCH ON HEALTH ASPECTS OF MICROWAVE RADIATION. *(Eng)* McRee, D. I. (Natl. Inst Environmental Health Sciences, P.O. Box 12233, Research Triangle Park, NC 22209). *Bull NY Acad Med* 55(11): 1133-1151; 1979 (5 refs).

Soviet Union and Eastern European research on the biologic effects of microwave radiation is reviewed. Soviet research has stressed human clinical studies and long-term, low-level effects on whole animal systems. Soviet, as well as Polish and Czechoslovakian, investigators have reported an "asthenic syndrome" in occupationally exposed workers that is characterized by headaches, irritability, fatigue, sleep disturbances, pains in the chest, and a general feeling of ill-being. Reports of animal studies by Soviet and Polish investigators at exposure power densities of ≤ 10 mW/cm^2 include effects on the central nervous system, behavior, cardiovascular system, hematology, blood biochemistry, immunology, endocrinology, metabolism, and reproductive function. The current Soviet standard for occupational exposure to continuous wave fields for a working day is 0.01 mW/cm^2 compared with 10 mW/cm^2 in the United States.

6510 THE "STORY" OF NONIONIZING RADIATION RESEARCH. *(Eng)* Susskind, C. (Univ. California, Berkeley, CA). *Bull NY Acad Med* 55(11): 1152-1163; 1979 (19 refs).

A general historical review of nonionizing radiation research dating from the late 1800s to the present is informally presented. Pioneers in the field of nonionizing electromagnetic radiation include Jacques Arsene d'Arsonval, who measured the effects of low-frequency sinusoidal currents on muscles; Heinrich Hertz, who demonstrated the existence of electromagnetic waves; Nikola Tesla, who demonstrated that oscillations around 20 kHz could not be perceived by the human body; and Eli Thomson, Paul Odin, who worked with d'Arsonval in the 1890s on the clinical applications of high-frequency currents, introduced the use of high-voltage, high-frequency currents in surgery. The first textbook on diathermy, published in 1913 by Karl Franz Nagelschmidt, advanced the idea that high-frequency currents heated by molecular agitation and oscillation. Pioneering work with diathermy equipment for electrosurgery began with Goerge Austin Wyeth in the 1920s. Harvey Williams Cushing, Dan Mackenzie, and John Anderson. The first attempts to study the effects of shortwave radiation on animals were made by Joseph William Schereschewsky in American and Erwin Schliephake in Germany in the 1930s. During World War II, the mass use of radio and radar inspired the Department of Defense to mount the Tri-Service program (mid-1950s) to study the effects of microwave radiation on servicemen who operated and repaired the military radar equipment. When the Tri-Service program ran out in the mid-1960s, there was a hiatus until the early 1970s, when new developments, such as Litton Industries' and Raytheon's inexpensive magnetrons and magnetron power supplies, opened up a mass market for microwave household appliances. The BRH became interested and in 1968 the Radiation Control for Health and Safety Act was passed. Presently, several influential committees are responsible for much of the interest the government is displaying in this field: American National Standards Institute, National Council on Radiation Protection and Measurements, and the Electromagnetic Radiation Management Advisory Council.

6511 CHAIRMAN'S INTRODUCTION: SESSION III. *(Eng)* Eisenbud, M. (Inst. Environmental Medicine, New York Univ. Medical Center, Sterling Forest, Tuxedo, NY). *Bull NY Acad Med* 55(11): 1164-1165; 1979 (no refs).

The role of epidemiologic research in investigating the biologic effects of microwaves is briefly discussed, and it is suggested that such research will provide most of the information needed to put public policy decisions on a rational basis.

6512 EPIDEMIOLOGIC APPROACH TO THE STUDY OF MICROWAVE EFFECTS. *(Eng)* Silverman, C. (Div. Biological Effects, BRH, FDA,

HFX-101, 5600 Fishers Lane, Rockville, MD 20857). *Bull NY Acad Med* 55(11): 1166-1181; 1979 (28 refs).

The objectives, methods, and application of an epidemiologic study of United States' naval personnel occupationally exposed to microwaves during the Korean War are reviewed. The following reported or suspected adverse effects of microwaves, none of which appeared pathognomonic for microwave radiation, were studied: ocular effects, nervous and behavioral effects, congenital anomalies, and cancer. The study protocol involved the use of largely automated military and veterans' records to analyze the following endpoints: mortality, hospitalized illness in Naval and VA hospitals, and disability. Occupational groups were classified as probably maximally exposed (those repairing radar equipment) and probably minimally exposed (those operating radar equipment). Each of the two groups comprised about 20,000 individuals. An index of potential microwave exposure of individuals, called the Hazard Number, was constructed for those men whose individual records were reviewed. The results indicated that differential health risks associated with potential occupational exposure to radar in the Navy more than 20 yr ago are not apparent with respect to long-term mortality patterns or hospitalized illness around the period of exposure, two endpoints for which there was virtually complete information for the total study group. Later hospitalization (in VA facilities only) and awards for service-connected disability, the two other endpoints examined, provided incomplete information. While some significant differences among the occupational groups classified by level of potential exposure were found with respect to all of the endpoints studied, the differences could not be interpreted as a direct result of microwave exposure.

6513 EPIDEMIOLOGIC DATA ON AMERICAN PERSONNEL IN THE MOSCOW EMBASSY. *(Eng)* Pollack, H. (George Washington Univ., Washington, DC). *Bull NY Acad Med* 55(11): 1182-1186; 1979 (1 ref).

Epidemiologic data on American personnel exposed to microwave radiation in the Moscow Embassy between 1953 and 1976 are presented. Prior to May 1975, the Embassy was exposed to a single source of radiation that illuminated the west facade, essentially from the sixth floor to the roof at a maximum intensity of 5 $\mu W/cm^2$ for about 9 hr/day. From the end of May 1975 to early February 1976, there were two sources of radiation, one illuminating from the south and one from the east. The maximum measured level of radiation at one point was 18 $\mu W/cm^2$ for 18 hr/day. However, the intensity to which the Embassy employees were routinely exposed was much lower and varied depending on the wall, furniture, and distance from the windows. In a Johns Hopkins study, an exhaustive comparison of the health status of the State Department employees who had served in Moscow with those who had served in other Eastern European posts during the period of irradiation revealed no differences in health status as indicated by their mortality experiences and a variety of morbidity measures. No convincing evidence was discovered that would directly implicate the exposure to microwave radiation experienced by the Moscow Embassy employees in the causation of any adverse health effects.

6514 CLINICAL APPLICATIONS OF MICROWAVE RADIATION: HYPERTHERMY AND DIATHERMY. *(Eng)* Davis, J. B. (Bureau Medical Devices, FDA, Silver Spring, MD). *Bull NY Acad Med* 55(11): 1187-1192; 1979 (14 refs).

Frequencies assigned for clinical microwave hyperthermia and diathermy are reviewed along with indications considered acceptable by the FDA for the therapeutic use of these heat treatments. Diathermy as an adjunct procedure to conventional treatment methods to produce tissue heat has been approved by the FDA. The use of diathermy for therapy or treatment is based on the absorption characteristics of radio frequency electromagnetic fields in tissues and on physiologic responses, e.g., production of an increase in temperature in the range of 40 to 45 C that is considered necessary for effective therapy. The frequencies assigned for shortwave diathermy are 13.56, 27.12, and 40.68 MHz; most conventional shortwave diathermy devices operate at 27.12 MHz. The band frequencies assigned for microwave diathermy are 915, 2,450, 5,850, and 18,000 MHz. Presently available units operate at a frequency of 2,450 MHz; the 915-MHz frequency band is being used experimentally. Devices that are being used for clinical hyperthermia operate at frequencies assigned to shortwave diathermy. Legislation that was enacted as the Medical Device Amendments in May 1976 provides regulatory authority for the FDA to determine if medical devices are safe and effective for their intended uses.

6515 RADIATION AND HYPERTHERMIA. *(Eng)* Johnson, R. J. (Dept. Radiation Medicine, Roswell Park Memorial Inst., Buffalo, NY); Subjeck, J. R.; Moreau, D. Z.; Kowal, H.; Yakar, D. *Bull NY Acad Med* 55(11): 1193-1204; 1979 (29 refs).

The use of clinical radio frequency or microwave hyperthermia immediately before, during, or after ionizing radiation exposure or at a separate time is discussed in relation to tumor cell destruction in cancer therapy. Normal tissue and tumor hyperthermia in the 41-42 C range used at a separate time from ionizing radiation selectively damages cells with a low pH and does not affect radiation repair. Temperatures in the 43-45 C range damage oxygenated normal and tumor cells. Frequencies that have been used in clinical or experimental hyperther-

mia include 13.56, 500, 915, and 434 MHz. Hyperthermia is currently indicated for patients where differential heating can be obtained, such as for metastatic lymph nodes that lie within 5 cm of the skin's surface. New heating methods and thermometry are required to treat deep tumors in the thorax and abdomen.

6516 DIAGNOSTIC AND THERAPEUTIC USES OF RADIOFREQUENCY FIELDS. *(Eng)* Frazer, J. W (Dept. Diagnosis, Dental Sch., Univ. Texas Health Science Center, San Antonio, TX); McDavid, W D.; Millner, M. *Bull NY Acad Med* 55(11): 1205-1215; 1979 (56 refs).

Diagnostic and therapeutic uses of radio frequency (RF) fields are reviewed. RF fields have been shown to control local cell-mediated immune responses, produce alterations in tumor growth, produce effects on the circulating blood elements, and exert effects on bone structure, fracture healing, and wound healing From a diagnostic standpoint, some practical demonstrations of RF imaging of internal human structures have been performed. A specific form of RF imaging that has been used experimentally since about 1971 is nuclear magnetic resonance imaging. This type of imaging depends to some extent on the use of principles of near field scanning and inverse scattering that are reasonably well developed theoretically but still require considerable effort to produce medically useful equipment.

6517 POTENTIAL INTERFERENCE WITH MEDICAL ELECTRONIC DEVICES. *(Eng)* Reis, R. (Bureau Medical Devices, FDA, Silver Spring, MD). *Bull NY Acad Med* 55(11): 1216-1221; 1979 (18 refs)

The potential interference of nonionizing electromagnetic radiation (NIER) with medical electronic devices is discussed. NIER can adversely affect diagnostic and therapeutic medical devices that process bioelectric signals, transducer electrical signals, or radiotelemetered signals. Frequencies of interfering radiation range from below 50 Hz to beyond 1 GHz. These effects are mitigated by limiting the level of emissions where medical devices are likely to be used and by decreasing the susceptibility of the devices to NIER. The devices most susceptible to interference from NIER are those that utilize low level electrical signals to gather diagnostic information or to perform a therapeutic function. Examples of various sources of NIER that can interfere with medical devices include electrosurgical units, diathermy machines, electrical device cords, motors, fluorescent lights, television, frequency-modulated and citizen band signals, lightning, and solar flares. Pacemakers are the devices that are most frequently associated with dangers from electromagnetic interference. Actual or potential pacemaker interference has been reported from antitheft devices, microwave ovens, microwave search radars, citizen band radios, electric motors, ignition systems, and arc welders. The Bureau of Medical Devices of the FDA is developing guidelines for medical device susceptibility.

6518 GENERAL DISCUSSION: SESSION IV. *(Eng)* Pollack, H. (George Washington Univ., Washington, DC); Davis, J. B.; Johnson, R.; Frazer, J. W.; Reis, R. *Bull NY Acad Med* 55(11): 1222-1230; 1979 (no refs).

A general discussion concerning developments in microwave (MW) and radio frequency (RF) wave research is presented. The topics discussed include electromagnetic (EM) applicators, MW tomography, pacemaker reliability, RF imaging, and the effects of MW irradiation on bacteria. Two recent developments in EM applicators for hyperthermia are a lower frequency broad band applicator that obtains deeper heating of local tissue and an EM applicator for whole body hyperthermia. MW tomography and the use of interrogating energy have enabled noninvasive determination of functional specificities that cannot be obtained with any other method. The longevity of pacemakers and their reliability in the face of EM interference were also discussed: hermetic sealing of pacemakers makes them slightly less permeable to EM radiation. Other topics that were briefly discussed include 1) the irradiation of the U.S. Embassy in Moscow followed by the tentative increase in the Russian maximum exposure standard for MW to 5 μW and 2) RF imaging for diagnostic purposes including the possibility of nuclear magnetic resonance as a locator and electron/paramagnetic resonance as a treatment modality.

6519 ESTABLISHING SAFETY STANDARDS. *(Eng)* Shore, M. L. (BRH, FDA, Rockville, MD) *Bull NY Acad Med* 55(11): 1231-1239; 1979 (no refs)

The establishment of safety standards for exposure to radio frequency and microwave radiation is discussed. The WHO is currently developing a criteria document on microwaves that will review existing knowledge in this area and make some recommendations that may have a bearing on national microwave standards and on microwave safety in the future The European Office of World Health is developing a manual on nonionizing radiation, with one chapter specifically concerned with microwave radiation; this manual will also review existing knowledge and potentially influence future standards development In the United States, NIOSH is developing a criteria document on radio frequency microwaves. This document will review the scientific literature and will make a recommendation for human occupational exposure that will be transmitted to OSHA for possible promulgation as an enforceable

occupational standard. The regulatory agencies that are part of the Interagency Regulatory Liaison Group (FDA, EPA, OSHA, and the Consumer Products Safety Commission) are currently in the process of developing a basis for consistent regulatory action in the area of radio frequency and microwave emissions. This will include a review of the adequacy of existing exposure standards, including those currently recommended by the American National Standards Institute (ANSI), OSHA, and those in use by the Department of Defense. The National Academy of Sciences may also participate in this review. Finally, the American National Standards C-95 Committee, which published the 10 mW/cm² safety standard for exposure of personnel, has been determining the position it will take with respect to ratification or modification of this ANSI exposure standard. It is suggested that the safety standards should be developed openly, with the broadest possible interaction between all concerned parties, including members of the general public, state and federal health agencies, and industry. The basis for all decisions should be carefully documented.

6520 THE MICROWAVE SYNDROME. *(Eng)* Pollack, H. (George Washington Univ., Washington, DC). *Bull NY Acad Med* 55(11): 1240-1243; 1979 (no refs).

A new disease, the microwave syndrome, is recognized. The recent publicity of the radiation of the United States Embassy in Moscow, coupled with Senate hearings on radiation health and safety, the impact of the Canadian proposals to lower their general population nonionizing radiation standard, and the numerous reports on nonionizing radiation appearing in the national news media have combined to increase public awareness, interest, and anxieties about the effects of nonionizing radiation. Examples of irresponsible reporting by the news media concerning the microwave irradiation of the U.S. Embassy in Moscow are presented. In contrast to these reports, a study conducted by the Johns Hopkins University School of Public Health and Hygiene concluded that, at the time of the report, there was no evidence discovered to implicate microwave radiation exposure in the development of any adverse health effects in exposed U.S. Embassy personnel.

6521 PUBLIC EDUCATION AND INTEREST IN ENVIRONMENTAL FACTORS. *(Eng)* Greenberg, D. S. (Washington Post, Washington, DC) *Bull NY Acad Med* 55(11): 1244-1250; 1979 (no refs).

Factors contributing to public confusion about the effects of exposure to microwaves and other types of environmental pollutants are discussed. The public distrust and suspicion of microwaves is attributed to frailties of the press, lack of unanimity in the scientific community, and the presence of large gaps in the knowledge of microwave exposure effects. Specific examples of ignorance in the scientific community and misinformation in the press are cited.

6522 A LOCAL HEALTH AGENCY APPROACH TO A PERMISSIBLE ENVIRONMENTAL LEVEL FOR MICROWAVE AND RADIOFREQUENCY RADIATION. *(Eng)* Solon, L. R. (Bureau Radiation Control, New York City Dept. Health, New York, NY). *Bull NY Acad Med* 55(11): 1251-1266; 1979 (28 refs).

Scientific justification for a proposed New York City Health Department regulation for setting maximum permissible levels of potential exposure to microwave and other radio frequency radiations for members of the general public in uncontrolled or unregulated areas is presented. The recommended regulation was derived from the following considerations. Biologic and clinical effects have been exhibited on a sufficiently broad scale by laboratory experiments and clinical observation to demonstrate the potential for physiologic impairment in humans from microwave and radio frequency radiation from various power or energy density levels. A summary of the biologic effects and clinical observations is presented. The very approximate threshold for some observable effects of varying public health implications appears to be between 1 and 10 mW/cm² for noncontinuous exposures. Evaluating available research evidence, an occupational permissible level of 0.5 mW/cm² would be indicated; this is a factor of 20 less than the current OSHA guidelines for working areas of 10 mW/cm². Employing an additional safety factor of 10 for a public environmental standard, a permissible level of 50 μW/cm² is arrived at for unregulated or uncontrolled areas available to the public. The proposed New York City Health Code regulation applies to microwaves and radio frequency stationary transmitters. However, the biologic considerations discussed also apply to the emissions of mobile units, the hazards of which are incompletely evaluated and deserve public health surveillance. The maintenance of environmental permissible levels substantially below occupational permissible levels recognizes that the public environment is not subject to the same presumed level of biomedical surveillance and detailed health and safety awareness as the occupational work place.

6523 THE COMMITTEE ON MAN AND RADIATION: A COMMITMENT TO THE PUBLIC INTEREST. *(Eng)* Justesen, D. R. (VA Medical Center, 4801 Linwood Blvd., Kansas City, MO 64128). *Bull NY Acad Med* 55(11): 1267-1273; 1979 (no refs).

Activities of the Committee on Man and Radiation are reviewed. The Committee was established in 1972 as a voluntary activity of the Technical Activities Board of the IEEE to fill the need for a formally constituted

body of scientists in the United States with a collective expertise in the physical, engineering, biologic, and medical aspects of nonionizing electromagnetic radiation. The fundamental charge of the Committee is to educate, and this may be accomplished by the following methods: participating in meetings of the IEEE and allied engineering societies; by conducting formal courses; by appearing on radio and television; by drafting position papers; by writing letters, reviews, and editorials; by participating in groups that advise the Congress and the executive departments; by supporting and participating in programs of international scientific exchange; and by participating in activities of many professional and scientific societies. Three issues of particular concern to Committee members focus on the unresolved question of the effects of ultra-long-term exposure of human beings to fields greater in intensity than 100 $\mu W/cm^2$. These issues are identified with industrial radio frequency heaters, thousands of which are being operated in the plastics, leather, and lumber industries by women of childbearing age; with the small civil but relatively larger engineering populations that are exposed to emissions associated with very high frequency television and frequency modulated broadcasts, which are at critical wavelengths with respect to resonant (enhanced) absorption of radio frequency energy by human beings; and with the proposed solar-powered satellite, which would shower the biosphere with microwaves for decades. A fourth issue arises from the increasing clinical use of radio frequency diathermy.

6524 AN OVERVIEW. *(Eng)* Eisenbud, M. (Inst. Environmental Medicine, New York Univ. Medical Center, Sterling Forest, Tuxedo, NY). *Bull NY Acad Med* 55(11): 1274-1278; 1979 (no refs).

In an overview of the industrial use of microwaves for more than 40 yr, it is suggested that some assurance can be found in the absence of microwave-related injuries. However, emphasis is placed on the need for continued investigation and, in particular, for epidemiologic studies of microwave-exposed populations. With this continued research, it is suggested that it would take only two more years to state unequivocally whether there is an occupational health hazard from microwave exposures. If there is no occupational health hazard then the public can accept the beneficial applications of microwaves and can be assured that there is no danger from environmental exposure as public exposure is much lower than occupational exposure.

6525 GENERAL DISCUSSION: SESSION V. *(Eng)* Healer, H. J. (Natl. Telecommunication and Information Admin., U.S. Dept. Commerce, Washington, DC 20005); Shore, M. L.; Pollack, H.; Greenberg, D. S.; Solon, L. R.; Hunt, E. L.; Eisenbud, M. *Bull NY Acad Med* 55(11): 1279-1296; 1979 (no refs)

A general discussion session on topics dealing with the health aspects of microwave and radio frequency radiation is presented. Topics discussed include: the rationale for setting a public environmental exposure standard of 50 $\mu W/cm^2$; functions of the Electromagnetic Radiation Management Advisory Council; differences in biologic response with different waveforms, e.g., modulated and continuous wave radiation at the same average power density; factors affecting the coupling of external energy to the absorbed energy that produces biologic effects; problems with the OSHA standard in terms of enforcement and units of measurement; the need to obtain near-field dosimetry solutions; the need to develop criteria to be used by physicians in examining people exposed to radio frequency and microwave radiation; the problem of using power density as a descriptor of potential hazard; and the need to distinguish between emission, exposure, and dose.

6526 POPULATION EXPOSURE TO VHF AND UHF BROADCAST RADIATION IN THE UNITES STATES. *(Eng)* Tell, R. A. (Office Radiation Programs, Electromagnetic Radiation Analysis Branch, EPA, P.O. Box 18416, Las Vegas, NV 89114); Mantiply, E. D. *Proc IEEE* 68(1): 6-12; 1980 (11 refs).

In an EPA study, numerous and widely distributed mesurement points, generally selected on the basis of population distributions, located in high density metropolitan areas of the United States were used to determine the ambient exposure levels of radio frequency and microwave energy. EPA estimates of population exposure to very-high frequency and ultra-high frequency broadcast radiation (54-806 MHz) in the U.S. were made based on measurement data obtained at 486 locations distributed throughout 15 large cities, collectively representing approximately 14,000 measurements of signal field intensity. A computer algorithm was developed that used these measurements to estimate the broadcast exposure at some 47,000 census enumeration districts within the metropolitan boundaries of these 15 cities. A median exposure level of 0.0048 $\mu W/cm^2$ (range, 0.0020-0.020 $\mu W/cm^2$) time averaged power density was determined for the population of the 15 cities studied, the cumulative population of which represents 20% of the total U.S. population. It was also estimated that greater than 99% of the population receives exposures <1 $\mu W/cm^2$, while 95% are exposed to <0.1 $\mu W/cm^2$. The frequency modulated (FM) radio broadcast service is responsible for most of the continuous illumination of the general population.

6527 OCCUPATIONAL EXPOSURE TO RADIO-FREQUENCY ELECTROMAGNETIC

FIELDS. *(Eng)* Mild, K. H. (Dept. Occupational Health, Natl. Board Occupational Health Safety, Umea Hosp., S-901 85 Umea, Sweden). *Proc IEEE* 68(1): 12-17; 1980 (23 refs).

Measurements of electric and magnetic field strength levels near various industrial radio frequency emitting sources in Sweden are reported. Electric and magnetic field sensitive instruments with one-dimensional antennas were designed, constructed, and calibrated. Electromagnetic fields near plastic welding machines operating at a frequency of 27 MHz and at power outputs ranging from 3 to 6 kW were made at the following operator locations: eyes, genitalia, hands on control panel, and hands near electrode. The electric fields strengths at these locations ranged from 200 to 900+, 170 to 900+, 820 to 900+, and 900+ V/m, respectively; the magnetic field strengths at these locations ranged from 0.3 to 1.6+, 0.2 to 1.3, 0.9 to 1.5, and 2.8+ A/m, respectively. Measurements of field strengths near shortwave diathermy machines operating at 27 MHz indicated that stray fields are very dependent on the type of electrodes used. The worst case, from an occupational exposure standpoint, was seen with glass capsule electrodes; 80 cm away from the electrodes the electric field was about 430 V/m for a far field power density of 500 W/m^2, and the magnetic field was 1.2 A/m at a distance of 60 cm from the electrodes. Measurements near a surgical diathermy unit operating at a frequency of 0.7 MHz with a power output of 200 W indicated electric fields of well over 1,000 V/m at 5 cm from the lead and probe. Measurements immediately in front of the transmitting dipoles on the outside of a television tower operating at a frequency of 196 MHz revealed electric and magnetic field strengths of greater than 1,000 V/m and greater than 3 A/m, respectively. Measurements near portable induction heaters operating at frequencies of 3.8 and 10.3 kHz indicated that the maximum magnetic flux density to which the hands of the operator could be exposed was 25 millitesla (mT); however, in most cases, the flux density was less than 1 mT on the hands. The field strength on other parts of the operator's body was considerably lower than 1 mT.

6528 MEASUREMENT OF ELECTRIC- AND MAGNETIC-FIELD STRENGTHS FROM INDUSTRIAL RADIO-FREQUENCY (6-38 MHz) PLASTIC SEALERS. *(Eng)* Conover, D. L. (NIOSH, 4676 Columbia Parkway, Cincinnati, OH 45226); Murray, W. E.; Foley, E. D.; Lary, J. M.; Parr, W. H. *Proc IEEE* 68(1): 17-20; 1980 (5 refs).

Electric and magnetic field strength measurements were performed on industrial radio frequency plastic sealers using field strength monitors that were constructed and calibrated for near-field exposure measurements by the NBS and Narda Microwave Corporation. Near-field measurements were necessary because the radio frequency sealer operators were less than one free space wavelength from the sealers. The sealers were characterized according to operating frequency (6.0-38.9 MHz), duty cycle (0.025 to >0.500), and nominal power output (0.25-25.0 kW). These measurements showed that at least 60% of the sealers emitted electric field strengths in excess of the American National Standards Institute (ANSI) C95.1-1974 guideline of 200 V/m and that at least 29% of the sealers exceeded the ANSI guideline for magnetic field strength exposure of 0.5 A/m. All of these measurements were corrected for duty cycle, which was typically 0.051-0.200. The following observations were also made. First, shielding can substantially reduce operator exposure. Second, exposure from adjacent sealers can be comparable to that received from the radio frequency sealer being surveyed. Third, all radio frequency sealers surveyed were operated by women. Finally, field strengths measured at seven anatomic locations of the operators (eyes, neck, chest, waist, gonads, knees, and ankles) showed considerable differences.

6529 STATE OF THE KNOWLEDGE FOR ELECTROMAGNETIC ABSORBED DOSE IN MAN AND ANIMALS. *(Eng)* Gandhi, O. P. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112). *Proc IEEE* 68(1): 24-32; 1980 (31 refs).

The current knowledge on electromagnetic energy (EM) absorption by man and animals is reviewed. Much of the research to date has been concerned with experimentally and mathematically simple plane-wave, far-field irradiation conditions, but recent research has included studies on ground and reflecting surfaces of high conductivity and studies on multiple animal systems. The electromagnetic absorbed dose for man and animals at various frequencies (10 MHz-10 GHz) is given for the plane wave irradiation for different orientations of the body relative to incident fields. Also included are the results for the whole-body absorption for conditions of electrical contact with ground and in the presence of reflecting surfaces of high conductivity and multiple animals. The data are given for the distribution of power deposition in man models for the resonance conditions of highest whole-body electromagnetic absorption. Results obtained with proportionately scaled saline- and biologic-phantom-filled models of man have been confirmed by experiments with small laboratory animals (25-g mice to 2,250-g rabbits). It is demonstrated that the electromagnetic densitometry is not of primary importance and that for a given power density the absorbed dose can vary by orders of magnitude, depending on the frequency, animal size and orientation, and physical environment. It is concluded that information is lacking for realistic conditions of exposure such as the effects of finite size, finite conductivity, ground and reflectors, and for the problem of near-field and/or partial body exposures such as are encountered by workers involved in the operation of electromagnetic radiation

equipment for communications, radar, and for industrial and biomedical applications.

6530 ELECTROMAGNETIC DOSIMETRY FOR MODELS OF HUMANS AND ANIMALS: A REVIEW OF THEORETICAL AND NUMERICAL TECHNIQUES. *(Eng)* Durney, C. H. (Dept. Electrical Engineering and Bioengineering, Univ. Utah, Salt Lake City, UT 84112). *Proc IEEE* 68(1): 33-40; 1980 (46 refs)

Theoretical and numeric techniques of electromagnetic dosimetry for models of humans and animals are reviewed. Analytical techniques reviewed include the analysis of planar and spherical models, long-wavelength analysis of spheroids and ellipsoids, the analytical solution for cylindrical models, spheroidal wave functions, and empirical techniques. Numeric techniques discussed include the moment method and the extended boundary condition method. Although much information is available about far-field specific absorption rates (SAR), it is concluded that more data are needed in the 500-1,000-MHz range for man-size models. Also, more data are needed for local SAR values, particularly in inhomogeneous models More work is required in the area of calculating the actual temperature produced by the SAR. An important new area of current research is the calculation of the SAR resulting from near-field irradiation, which is often a more real situation than far-field irradiation. The ultimate need in dosimetry is a method for calculating the expected SAR in an absorbing body from a knowledge of the fields present in the space to be occupied by the absorber.

6531 MICROWAVE BIOLOGICAL EFFECTS: AN OVERVIEW. *(Eng)* Michaelson, S. M. (Dept. Radiation Biology and Biophysics, Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14642). *Proc IEEE* 68(1): 40-49; 1980 (99 refs).

An overview of studies on the biologic effects of microwave radiation is presented. The reliability of laboratory studies and their results depends on the selection of the animal model, the methods used to study the biologic processes in the animals, and the extrapolation of data from animals to man. These studies include microwave-induced effects on basic physiology, cellular effects, genetic effects, effects on growth and development, effects on the gonads, neuroendocrine effects, metabolic effects, effects on the nervous system, effects on the blood-brain barrier, behavioral effects, cardiovascular effects, hematopoietic effects, effects on immunity, auditory response to microwaves, ocular effects, the perception of microwave energy as a function of cutaneous thermal sensation or pain, and the effects of microwaves on general health. Although most investigators accept the fact that high power density levels of microwaves can result in pathophysiologic manifestations of a thermal nature, some reports have suggested that low power density microwaves can affect neural and immunologic function in animals and man. Most of these reports have emanated from the USSR and other Eastern European countries. Most of the reported low level effects relate to behavioral and central nervous system changes. A critical review of studies on the biologic effects of microwaves indicates that many of the investigations suffer from inadequacies of either technical facilities and energy measurement skills or insufficient control of the biologic specimens and the criteria for biologic change.

6532 MICROWAVE CATARACTOGENESIS. *(Eng)* Cleary, S. F. (Dept. Biophysics, Medical Coll. Virginia, Virginia Commonwealth Univ., Richmond, VA 23298). *Proc IEEE* 68(1): 49-55; 1980 (52 refs).

Studies on microwave cataractogenesis are reviewed. Microwave radiation has been shown to induce damage in ocular tissues, with the site of damage depending on the wavelength of radiation and the mode of exposure. The extent of damage is primarily dependent on the radiation intensity or power density and total exposure duration. In the frequency range from 1 to 10 GHz, the lens appears to be the ocular tissue of greatest sensitivity. Most investigations of experimental microwave cataractogenesis have involved single or multiple subthreshold exposures in the intensity range of 80-500 mW/cm^2. Time-intensity relationships for cataract induction in the rabbit as well as experimental studies of microwave-induced ocular heating suggest the involvement of thermal damage to lens tissue. The induction of lens opacification following repeated exposures at intensities below the threshold for single-dose exposures suggests a cumulative component of lens damage and the existence of repair mechanisms. Repair mechanisms are also indicated in experimental biochemical studies of microwave effects on rabbit lens epithelial cells with a 10- to 20-day cellular recovery period. Over 50 cases of human cataract induction have been attributed to microwave exposures, primarily encountered in occupational situations involving acute exposure to presumably relatively high intensity fields. Although dosimetric data are not adequate to specify exposure thresholds, acute lens opacification in humans appears to involve thermally induced lens damage that occurs at exposure intensities of ≥ 100 mW/cm^2. Epidemiologic studies of workers exposed to microwaves have in some cases suggested that occupational exposure may result in lens alterations, but there is no evidence that such effects are associated with visual impairment or cataract formation.

6533 MAMMALIAN TERATOGENESIS AND RADIO-FREQUENCY FIELDS. *(Eng)* O'Connor, M. E. (Dept. Psychology, Univ. Tulsa, Tulsa, OK 74104). *Proc IEEE* 68(1): 56-60; 1980 (31 refs).

Studies on radio frequency field-induced teratogenesis in mammals are reviewed. All investigations of mammalian teratogenesis after experimental exposures to radio frequency energy have involved rats or mice, and most of the studies have involved acute exposures to 2,450-MHz continuous wave microwaves at high power densities. The most common result from fetal exposure to microwaves appears to be a nonspecific general response, i.e., reduced or retarded gains of body mass. However, specific anatomic abnormalities (especially exencephaly) and an increase in resorption of the fetus have also been observed. Most of the defects that have been observed followed acute exposures to highly intense fields that produced marked increments of body temperature. There are no conclusive results from the few studies conducted with low-level long-term exposure to microwaves. Whether teratogenesis is derived primarily from thermal stress or from frequency specific action of the microwave field or from a combination of the two has not been determined. There are no unequivocal reports of microwave-induced teratogenesis in the human being.

6534 MICROWAVE IRRADIATION AND THE BLOOD-BRAIN BARRIER. *(Eng)* Justesen, D. R. (Neuropsychology and Behavioral Radiology Lab., VA Medical Center, Kansas City, MO 64128). *Proc IEEE* 68(1): 60-67; 1980 (55 refs).

Earlier reports of altered blood-brain barrier (BBB) function in small animals after brief exposure to weak microwave fields (30-1,000 $\mu W/cm^2$, averaged) are reviewed in the light of more recently reported studies that have generally yielded negative findings. The physiologic data indicate that the tight junctions of the BBB's capillaries are loosened by microwaves only at high field strengths that markedly elevate brain temperature. Anatomic data reveal that the tight junctions apparently remain intact but that enhanced blood-to-brain vesicular transport of normally excluded tracer molecules occurs reversibly in small animals exposed for 2-8 hr to continuous waves at a moderate field strength (10 mW/cm^2). Recent conceptual and technical advances in the measurement of BBB function support the thesis that the early reports of altered permeability actually reflect microwave-induced changes in cerebral circulation.

6535 THE MICROWAVE AUDITORY PHENOMENON. *(Eng)* Lin, J. C. (Dept. Electrical and Computer Engineering, Wayne State Univ., Detroit, MI 48202). *Proc IEEE* 68(1): 67-73; 1980 (41 refs).

Studies of the microwave auditory phenomenon have demonstrated that human beings perceive an auditory sensation when the head is exposed to rectangular pulse-modulated microwaves with peak incident power densities on the order of 300 mW/cm^2 and average power densities as low as 0.1 mW/cm^2. The frequencies of these microwaves ranged from 200 to 3,000 MHz, and the pulse width varied from 1 to 100 μsec. The microwave sound appeared as an audible click, buzz, or chirp depending on such factors as pulse width and pulse repetition frequency of the impinging radiation. The induced sound was usually perceived as originating from within or near the back of the head. Experiments with laboratory animals have shown that electrophysiologic auditory activity may be elicited by exposing the animal's brain to rectangular pulses of microwave energy. The results of these experiments suggest that the microwave auditory phenomenon is evoked by a mechanism similar to that responsible for conventional sound reception and that the primary site of interaction resides peripheral to the cochlea. A comparison of the pressure amplitudes, such as those produced in a homogeneous planar layer of brain matter that is irradiated by a microwave pulse, indicates that the peak pressure due to thermal expansion is much greater than either radiation pressure or electrostriction. Theoretical analyses for a spherical brain based on the thermoelastic mechanism of interaction agreed with experimentally observed characteristics, and indicated that the induced sound frequency is only a function of the size and acoustic property of the brain.

6536 ADVANCES IN MICROWAVE-INDUCED NEUROENDOCRINE EFFECTS: THE CONCEPT OF STRESS. *(Eng)* Lu, S. T. (Dept. Radiation Biology and Biophysics, Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14642); Lotz, W. G.; Michaelson, S. M. *Proc IEEE* 68(1): 73-77; 1980 (46 refs).

Studies on microwave-induced neuroendocrine effects indicate that the acute effects of microwaves on hypothalamus-hypophyseal function are increased adrenocorticotropic secretion, decreased thyrotropic secretion, and decreased growth hormone secretion. These stereotyped changes can be observed simultaneously in rats acutely exposed to 2.45-GHz microwaves at 50, 60, or 70 mW/cm^2 for 1 hr. The characteristics of these changes of hypophyseal hormones constitute the pattern of stress reactions of animals. Neuroendocrine data are consistent with the hypothesis that the adenohypophyseal responses are the integral result of central nervous system processing of multiple signals from many body locations such that no single localization of absorbed energy is pivotal to the onset of a response. Factors such as circadian rhythmicity, stimulus intensity, and perhaps interspecies differences are important in determining the pattern of these responses. Thus, in addition to further studies to characterize the basic neuroendocrine response to

microwave exposure, studies are needed to determine the physiologic mechanism(s) by which this regulatory system is affected during microwave exposure.

6537 **EPIDEMIOLOGIC STUDIES OF MICROWAVE EFFECTS.** *(Eng)* Silverman, C. (Div. Biological Effects, BRH, FDA, 5600 Fishers Lane, Rockville, MD 20857). *Proc IEEE* 68(1): 78-84; 1980 (31 refs).

Epidemiologic studies of microwave bioeffects are reviewed. Such studies of microwave effects have been few in number and generally limited in scope. Two recent but not yet published studies, a study of United States Naval personnel occupationally exposed to radar and a study of American Embassy personnel in Moscow, exposed to long-term irradiation, have failed to demonstrate differential health risks associated with presumed exposure to microwave radiation. However, limitations of the studies preclude conclusions about possible microwave-related health effects. Epidemiologic data from numerous surveys of ocular effects in man suggest a possible earlier appearance of lens defects in microwave workers than in comparison groups. The only epidemiologic study of cataracts in microwave workers, a case-control study of World War II and Korean War veterans, has produced negative findings. In a small Swedish study, which included examinations for retinal as well as lens changes, a significantly higher proportion of retinal lesions in the central part of the fundus was found in microwave workers aged 26-40 yr than in controls. Occupational studies in the USSR and Eastern European countries have disclosed functional disturbances of the central nervous system in workers exposed to microwaves. The symptoms and signs included headache, fatigability, irritability, loss of appetite, sleepiness, sweating, thyroid gland enlargement, difficulties in concentration or memory, depression, and emotional instability. Another frequently described manifestation in these Eastern European studies was a set of labile functional cardiovascular changes including bradycardia (or occasional tachycardia), arterial hypertension (or hypotension), and changes in cardiac conduction. The only American epidemiologic study of some of these effects, the cohort study of American Embassy employees in Moscow and other Eastern European capitals, disclosed much symptomatology but no differences attributable to microwave exposure at intensities measured outside the Moscow Embassy. However, these levels were lower than exposures reported in the Russian occupational studies. Epidemiologic studies have failed to disclose any relationship between microwave irradiation and either cancer or congenital anomalies.

6538 **SOVIET AND EASTERN EUROPEAN RESEARCH ON BIOLOGICAL EFFECTS OF MICROWAVE RADIATION.** *(Eng)* McRee, D. I. (Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709). *Proc IEEE* 68(1): 84-91; 1980 (33 refs).

A review of Soviet and Eastern European research on the biologic effects of microwave radiation is presented along with some results from a cooperative program between the USSR and the United States in this area. An overview of Soviet and Eastern European literature indicates a large number of bioeffects at exposure levels below 10 mW/cm² and a significant number of biologic changes below 1 mW/cm². In a cooperative USSR-U.S. study of microwave bioeffects, the Soviets reported changes in bioelectric brain activity at 10, 50, and 500 μW/cm² in rats and rabbits exposed for 7 hr/day for 30 days to 2,375-MHz continuous wave (CW) radiation. Levels of 10 and 50 μW/cm² stimulated brain activity, while 500 μW/cm² suppressed activity. At 500 μW/cm², decreases in work capacity, investigative activity, and sensitivity to electric shock threshold in rats were reported. U.S. research on rats exposed to 5 mW/cm² of 2,450-MHz CW radiation for shorter exposure periods showed no statistical difference in electroencephalogram activity, no change in locomotion activity in a residential maze, and no change in performance on a fixed-ratio schedule of reinforcement below 5 mW/cm² (0.5 and 1.0 mW/cm²) but a trend toward a decrease in performance at 5 mW/cm² and a large decrease in performance at 10 and 20 mW/cm². To duplicate the Soviet results, a U.S. experiment was performed where rats were exposed to microwaves for 7 hr/day, 7 days/wk, for 3 mo at a power density of 500 μW/cm². This U.S. study disclosed a drop in sulfhydryl activity and blood cholinesterase as was reported in the USSR study. Blood chemistry at the end of the 3-mo exposure period indicated that the exposed animals suffered from aldosteronism relative to controls. The latter interpretation of the high sodium-low potassium levels found in the blood was confirmed by necropsy and histopathology of the adrenal glands, revealing that the zona glomerulosa was vacuolated and hypertrophied. In addition, all behavioral parameters assessed at the end of the 3-mo period revealed significant differences between groups in the same direction as those reported in the USSR study, i.e., increased threshold to foot shock detection, decreased activity in an open field, and poorer retention of an avoidance response when reassessed following conditioning.

6539 **STUDY OF EFFECTS OF LONG-TERM LOW-LEVEL RF EXPOSURE ON RATS: A PLAN.** *(Eng)* Guy, A. W. (Dept. Rehabilitation Medicine, Bioelectromagnetics Res. Lab., Univ. Washington, Seattle, WA 98195); Chou, C. K.; Johnson, R. B.; Kunz, L. L. *Proc IEEE* 68(1): 92-97; 1980 (18 refs).

A study designed to simulate the chronic exposure of man to 450-MHz radio frequency (RF) radiation at

an incident power density of 1 mW/cm² is described. The study consists of two phases. Phase I includes the construction of exposure waveguides, completion of dosimetric measurements, establishment of exposure facilities and data acquisition systems, and pilot studies. Phase II of the study will involve the exposure of 100 experimental rats (with 100 matched controls) to pulse-modulated 2,450-MHz RF fields at incident peak and average power densities of 140 mW/cm² and 560 μW/cm², respectively, for 22 hr/day, 7 days/wk, until 75% mortality of the control and exposed groups is reached. The modulation will consist of 16 pulse groups/sec (25 pulses/group) with a pulse duration of 10 μsec, a period of 500 μsec, and a pulse recurrence rate of 2,000 pulses/sec. The state of health of each animal will be assessed periodically throughout the exposure period until the above mortality percentage is reached. Biologic endpoints of the study will be blood chemistry parameters, mortality rates, histopathology, body weight, and food and water consumption.

6540 BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS ASSOCIATED WITH ELF COMMUNICATIONS SYSTEMS. *(Eng)* Grissett, J. D. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). *Proc IEEE* 68(1): 98-104; 1980 (29 refs).

Studies, conducted by an Ad Hoc Committee and the National Academy of Sciences, on the biologic effects of electric and magnetic fields associated with the United States Navy's proposed submarine communications system, which operates at extremely low frequencies, are reviewed. Over the last 10 years, the Navy has sponsored a variety of reseach to evaluate the environmental impact of this system. The land-based transmitting antenna for this system consists of insulated conductors 50-100 km long, grounded at each end, and driven by a generator such that the flow of current would be along the cable, into the ground, deep in the earth, and return to the other grounded end of the cable. The magnetic fields at the surface of the earth directly above a buried antenna element would average about 0.02 millitesla (mT), and the electric field gradient parallel to the cable would be 0.07 V/m. The National Academy of Sciences' review of research on the environmental impact of this system was performed in 1976 and dealt with the following subject areas: genetics, fertility, growth, development, cell growth and division, serum triglycerides, circadian rhythms, electrosensitive fish, insect behavior, bird orientation and migration, mammalian neurophysiology and behavior, effects on plants, and effects on soil organisms. Although the Academy recognized the possibility of a physiologic perturbation, it found no experimental or theoretical basis to assume that a potential hazard would exist at exposure levels of 0.02 mT and 0.07 V/m. Subsequent to this review, an experiment involving the exposure of 30 rhesus monkeys (with 30 matched controls) to extremely low frequency radiation for 22 hr/day continuously was performed. After more than 3 yr of exposure, the most significant finding is enhanced growth rate in exposed males. A new experiment is in progress at the Naval Aerospace Medical Research Laboratory to test the following hypotheses. Extremely low frequency fields have an effect on the neuroendocrine system. Voltage gradients in the experimental apparatus or in the soil near the antenna can provide direct testicular stimulation and affect growth rate in males. Extremely low frequency fields have a generalized metabolic effect that increases growth rate in both males and females.

6541 RF-FIELD INTERACTIONS WITH BIOLOGICAL SYSTEMS: ELECTRICAL PROPERTIES AND BIOPHYSICAL MECHANISMS. *(Eng)* Schwan, H. P. (Dept. Bioengineering, Univ. Pennsylvania, Philadelphia, PA); Foster, K. R. *Proc IEEE* 68(1): 104-113; 1980 (71 refs).

Electrical properties of tissues, macromolecular solutions, and cell membranes are summarized at frequencies from the extra-low frequency to microwave range. The electrical properties that were surveyed include conductivity, resistivity, and dielectric permittivity relative to free space. Previously presented dielectric data are supplemented by new results, and physical mechanisms for the observed temperature coefficients of the dielectric properties are discussed. For most material, permittivity and conductivity are frequency dependent or dispersive. It is concluded that the temperature coefficient varies with increasing frequency through the dispersion range from about -0.3 through a maximum of +2 and back to -0.3%/C. The dielectric data are discussed in terms of the interaction mechanisms that give rise to the observed relaxational effects, and it is concluded that the considerations presented do not suggest any weak nonthermal mechanism by which biologic systems could react to low-intensity microwave fields. However, it is suggested that the large dimensions necessary for biologic responses to weak microwave fields might be achieved by a cooperative reaction of a number of cells or macromolecules to the microwave stimulus, which increases the effective size of the structure and correspondingly reduces the threshold that is required for an effect.

6542 CELLULAR EFFECTS: MILLIMETER WAVES AND RAMAN SPECTRA–REPORT OF A PANEL DISCUSSION. *(Eng)* Jaggard, D. L. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Lords, J. L. *Proc IEEE* 68(1): 114-119; 1980 (21 refs).

A panel discussion entitled *Cellular Effects: Millimeter Waves and Raman Spectra*, which was held at the Bioelectromagnetics Symposium in Seat-

tle, Washington on June 22, 1979, is summarized, and detailed abstracts of the presentations are provided. The first topic of discussion concerned the spectroscopic details of Frolich's theory and the resulting model. This process permits the identification of methods by which certain key parameters of the theoretical model can be found experimentally. As a result of the intense absorption of water in this regime, it is recommended that emissivity, rather than absorption, effects should be studied and it is suggested that experimentation in the frequency region of 100 GHz might be appropriate. The second topic concerned experimental findings of possible positive results for colicin induction. The experimental design for the study of colicin induction should involve small well-defined systems such as organelles or vesicles; since most of the effects can be related to changes in the membrane, the use of fluorescent probes to detect small changes that might occur is recommended. Another topic of discussion involved the resolution of differences in biologic test systems and in radiation parameters that exist between various laboratories. Next, a description of a system used for millimeter wave absorption studies was presented and difficulties with water in the sample were reviewed along with work on frozen samples. With frozen samples, insertion losses are greatly reduced. However, no frequency specific absorption effects have been demonstrated in any of the biologic preparations tested in the millimeter regime. Initial efforts using Raman spectroscopy are in progress and significant problems involving fluorescence, Rayleigh scattering, and cell movement have been mostly resolved. The final presentation concerned the possibilities and drawbacks of Raman spectroscopy. The effects of physical parameters such as temperature and pressure on spectroscopic results were outlined, and the need for a very simple test system (e.g., a reconstituted vesicle containing biologically active enzymes) was emphasized.

6543 FREQUENCY AND POWER WINDOWING IN TISSUE INTERACTIONS WITH WEAK ELECTROMAGNETIC FIELDS. *(Eng)* Adey, W. R. (Res. Service, 151, VA Hosp., Loma Linda, CA 92357); NA *Proc IEEE* 68(1): 119-125; 1980 (47 refs).

Windowed bioeffects are discussed in terms of two types of tissue interactions with weak electromagnetic fields; one involves the direct interaction with extremely low frequency (ELF) fields and the other is induced by radio frequency (RF) or microwave (MW) fields amplitude modulated at low frequencies (LF). Fields raising tissue temperature orders of magnitude <0.1 C are capable of producing chemical, physiologic, and behavioral changes only within windows in frequency and incident energy; these changes are not attributable to raised temperature *per se*. For brain tissue, a maximum frequency sensitivity occurs between 6 and 20 Hz. Two different intensity windows have been detected, one involving ELF gradients of 10^{-5} to 10^{-4} V/cm and the other in ELF or LF modulated RF and MW fields at 10^{-1} to 10^{-2} V/cm. The former intensity window is at the level associated with navigation and prey detection in marine vertebrates and with control of human biologic rhythms, while the latter intensity window is at the level of the electroencephalogram in brain tissue. Coupling to living cells appears to require amplifying mechanisms that may be based on nonequilibrium processes with long-range resonant molecular interactions. These cooperative processes are recognized as important in immune and hormonal responses as well as in nerve cell excitation. Polyanionic proteinaceous material forming a sheet on cell membrane surfaces appears to be the site of detection of these weak molecular and neuroelectric stimuli.

6544 ELECTROMAGNETIC TECHNIQUES FOR MEDICAL DIAGNOSIS: A REVIEW. *(Eng)* Iskander, M. F. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H. *Proc IEEE* 68(1): 126-132; 1980 (40 refs).

Electromagnetic (EM) methods for medical diagnosis, especially their advantages and disadvantages, are reviewed. These include impedance plethysmography using low frequency EM fields (20-100 kHz), the use of 915-MHz microwaves for measuring lung water, EM imaging, microwave radiometry, the use of 10.525-GHz microwave Doppler radar for monitoring arterial wall movement, and an EM flowmeter for blood flow measurements. Except for the EM flowmeter, these techniques are still in the research stage, with their clinical application being restricted to specialized centers. One factor that contributes to the slow development of these techniques is the complexity of the interaction between EM waves and the human body. The EM flowmeter has reached a high standard of clinical performance and reliability. This device is based on the Faraday law of EM induction. If blood is flowing in a tube or blood vessel oriented at right angles to a magnetic field, then the mean velocity of blood flow can be calculated by measuring the potential difference across the diameter of the blood vessel. In spite of the wide use of the EM flowmeter in surgical applications, the following technical problems are sometimes encountered: electrocardiogram pick-up, zero-point drift and instability, and some other minor artifacts due to vessel drying and varying vessel diameter. EM diagnostic techniques appear promising, however, much more research is needed before the methods are ready for clinical use.

6545 PHYSICAL HYPERTHERMIA AND CANCER THERAPY. *(Eng)* Short, J. G. (BSD Corporation, Univ. Utah Res. Park, Salt Lake City, UT 84108); Turner, P. F. *Proc IEEE* 68(1): 133-142; 1980 (67 refs).

The use of physical hyperthermia in cancer therapy is discussed, with reference to electromagnetic (EM) coupling modalities and ultrasound. The application of hyperthermia to cancer therapy is based on the observation that malignant cells are generally more sensitive to heat than are normal cells in the temperature range of 41-45 C. In addition, most clinically apparent tumors (>1 cm in diameter) have blood perfusion rates less than 20% that of surrounding normal tissue. Coupling of EM energy to malignant tissue is through one of three modalities: capacitive, inductive, or radiative (microwave). Ultrashortwave diathermy at the industrial, scientific, and medical (ISM) frequencies of 13.56 and 27.12 MHz has been used with contact electrodes or with capacitor plates separated from the patient to produce more parallel field patterns and eliminate edge-heating effects. However, the alternating current produced by this form of heating may produce heating patterns that are difficult to predict because the current will follow paths of least resistance. Noninvasive applicators at ultra-high frequency-microwave frequencies are not required to be in contact with the body. Small animal experimentation is usually performed with noncontact horn antennas. Contact applicators are usually preferred for human use, and coupling efficiencies of approximately 95% are expected. As the frequency increases, the depth of penetration decreases until at 2,450 MHz, for an assumed 1-cm fat thickness, the energy is reduced to 40% of the incident level in the first 2-3 mm of skin. Although subcutaneous fat is relatively transparent to plane waves, little energy is available for the heating of deep tissues at this frequency. Hyperthermia improves at the next ISM frequency of 915 MHz. The frequency range of greatest clinical interest may be 100-1,000 MHz; however, in the United States, the next available ISM band is at 40.68 MHz. Ultrasound has also been used for inducing localized hyperthermia, and this technique offers the best focusing. However, problems with this technique include reflections, caviation, and bone heating.

6546 IMPLANTABLE RADIATORS FOR CANCER THERAPY BY MICROWAVE HYPERTHERMIA. *(Eng)* Taylor, L. S. (Dept. Electrical Engineering, Univ. Maryland, College Park, MD 20742). *Proc IEEE* 68(1): 142-149; 1980 (28 refs).

The use of implantable microwave radiators for the hyperthermic treatment of cancer is reviewed. Microwave radiator designs must take into account the wide variations in tumor geometry and thermal response as well as variations in dielectric properties. Simple radiators suitable for both solid and hollow organ implantation have been devised and tested in vitro and in animal experiments. The results have demonstrated a controlled localized heating of malignant internal structures. Experiments with cats and mice have shown that it is possible to obtain localized thermal distributions suitable for clinical hyperthermia over volumes on the order of 1 cm in radius in solid organs with single radiators and over larger volumes with radiator arrays using frequencies ranging from 0.4 to 3.0 GHz with powers below 8 W. Brain heating experiments with cats using a 2,450-MHz needle antenna showed predictable thermal profiles with no extraneous hot spots. The microwave radiation was confined to the target volumes with no detectable leakage, and thermal fields 2 cm below the cortical surface were controllable to fractions of a centimeter. The clinical feasibility of these radiators and the design of therapeutic regimens are currently being investigated in patients with glioblastoma multiforme and esophageal squamous cell carcinoma.

6547 STEADY MAGNETIC FIELDS IN NONINVASIVE ELECTROMAGNETIC FLOWMETRY. *(Eng)* Salles-Cunha, S. X. (Dept. Surgery and Neurosurgery, Medical Coll. Wisconsin, Milwaukee, WI 53226); Battocletti, J. H.; Sances, A. *Proc IEEE* 68(1): 149-155; 1980 (26 refs).

Transcutaneous electromagnetic flowmetry, which noninvasively measures the induced voltage generated by the flow of blood through a region immersed in a magnetic field, was used in conjunction with steady magnetic fields of less than 0.5 tesla to measure pulsatile popliteal, brachial, and bilateral common carotid blood flow in normal subjects, in patients with arteriovascular disease, and in subjects with arteriovenous fistula surgically created for hemodialysis. Flow rate was calculated from the measured voltages and geometric and electric parameters using equations developed for three-media (body segment-vessel-blood) cylindrical models based on electromagnetic theory. The 68 measurements taken in this study were in the expected range. For example, recordings of induced voltage signals for 2 min in nine normal subjects (18 limbs) indicated that peak popliteal flow was 499 ± 130 ml/min. Average pulsatile flow was 65 ± 22 ml/min, which was comparable to the average of the pulsatile component of blood flow measured during surgery through femoral-popliteal arterial grafts (64 ± 24 ml/min, 64 measurements). This average flow corresponds to approximately 2 ml/min/100 ml of tissue volume and it is comparable to determinations obtained with other techniques. Quantification of pulsatile bilateral common carotid arterial flow was possible. However, drift and voltage offset in the electrode-skin interface may be on the order of 1 μV/sec and a few millivolts, respectively, making the measurement of direct flow difficult.

6548 THE INACTIVATION OF RODENT BRAIN ENZYMES IN VIVO USING HIGH-INTENSITY MICROWAVE IRRADIATION. *(Eng)* Meyerhoff, J. L. (Walter Reed Army Inst. Res., Walter Reed Army Medical Center, Washington, DC 20012);

Lenox, R. H.; Brown, P. V.; Gandhi, O. P. *Proc IEEE* 68(1): 155-159; 1980 (25 refs).

The use of high-intensity microwave irradiation for inactivating rat brain enzymes and thus eliminating postmortem artifacts in heat-stable substrates is discussed. Studies comparing brain values of intermediary metabolites (e.g., creatine phosphate, adenosine triphosphate, adenosine diphosphate, pyruvate, glucose) showed that whole brain values obtained using a freeze blowing technique (approximately 0.5 sec) were comparable to values obtained with newer microwave inactivation techniques (inactivation times ranging from 0.4 to 2.0 sec). Microwave inactivation, unlike rapid freezing methods, permits the dissection of the brain into specific regions. However, one problem associated with microwave-induced inactivation of brain enzymes is the nonuniformity of the microwave field generated within the brain. This requires that the duration of microwave exposure be sufficient to inactivate enzymes in the least heated regions while at the same time preserving the structural integrity of the brain tissue. Another problem of microwave-induced enzyme inactivation at a frequency of 2,450 MHz is the requirement to immobilize the subject during sacrifice; forced immobilization is a potent stressor and it may introduce artifacts. Recent studies have shown that the pattern of energy absorption at 986 MHz is independent of angular position of the animal's head within the waveguide, and the use of this frequency with rats might eliminate the requirement for rigorous immobilization of the subject. For microwave-induced inactivation of brain enzymes to be reliable, the power source output and frequency, the impedance match with the load, and the incident and reflected power must be monitored and controlled; the heat stability of the substrate to be measured must also be demonstrated along with the adequacy of enzyme inactivation.

6549 CORNER-REFLECTOR APPLICATORS FOR MULTILATERAL EXPOSURE OF ANIMALS IN BIOEFFECT EXPERIMENTS. *(Eng)* Gandhi, O. P. (Dept. Electrical Engineering and Bioengineering, Univ. Utah, Salt Lake City, UT 84112); Hunt, E. L. *Proc IEEE* 68(1): 160-162; 1980 (8 refs).

A corner reflector applicator for multilateral quasi-plane wave exposure of animals to electromagnetic (EM) fields is described. The applicator not only offers the cleanliness (constant phase and magnitude) of plane-wave multilateral irradiation, but also allows considerably enhanced specific absorption rates with moderate power sources capable of creating far-field average power densities of no more than 5-10 mW/cm^2. In addition to its use for continuous wave irradiation, the applicator may also be useful for experiments with EM pulses, where peak power densities as high as 1-2 W/cm^2 are often needed to observe behavioral changes.

6550 CALORIMETRIC MEASUREMENTS OF MICROWAVE ENERGY ABSORPTION BY MICE AFTER SIMULTANEOUS EXPOSURE OF 18 ANIMALS. *(Eng)* Allen, S. J. (Radiation Sciences Div., U.S. Air Force Sch. Aerospace Medicine, Brooks Air Force Base, TX 78235); Hurt, W. D. *Radio Sci* 14(6S): 1-4; 1979 (3 refs).

A multiple-cell calorimetric system was used to determine the specific absorption rate (SAR) of each of 18 mice that were simultaneously exposed to 2.6-GHz continuous wave radiation. For determination of SARs, selected animals were first euthanized and sufficient time permitted to elapse for the carcasses to equilibrate to the ambient temperature. The mice were weighed when the calorimeter attained thermal equilibrium. Five cadavers were placed in the exposure cage, and the remaining 13 positions were occupied by live mice to simulate the actual exposure geometry. A sixth cadaver, the control, was placed in the chamber but away from the radio frequency field. The array of animals was placed 150 cm from the front edge of a standard-gain horn and was exposed to 2.6-GHz continuous wave radiation. The mice were exposed with the long axis of the body parallel to the vector of the electric field. Immediately following a 10-min exposure, the initial temperature of each calorimeter was measured, and one mouse carcass was placed in each of five calorimeters. Temperatures were recorded every 5 min. The final temperature at thermal equilibrium was measured and used to evaluate the rationalized temperature of the mouse on insertion in the calorimeter. After this six mice and six thermal controls were individually exposed to low-scatter 2.6-GHz fields while located on a Styrofoam table. The incident field was uniform within ±0.5 dB and was adjusted to 20 mW/cm^2 for three of the exposed animals (10-min exposure time). The other three animals were exposed to 40 mW/cm^2 for 5 min. SAR values determined in each of these experiments were normalized to the average power density of incident radiation. The mean normalized SARs for mice exposed to 20 mW/cm^2 for 10 min were 1.1 ± 0.08 W/kg/mW/cm^2 compared with 1.19 ± 0.14 W/kg/mW/cm^2 for mice exposed to 40 mW/cm^2 for 5 min. The average of seven power densities of the central positions of the animal array with no animals in the holders was 5% higher than the average of 11 peripheral measurements. The SARs associated with the seven inner positions averaged 12% higher than those of the periphery when all but one of the holders were occupied by animals. This increase is thought to be due to enhancement of field intensity that results from scatter, which is more predominant near the center than near the edges of the array.

6551 DESCRIPTIVE SUMMARY: RADIOFREQUENCY RADIATION DOSIMETRY HANDBOOK--SECOND EDITION. *(Eng)* Durney, C. H. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112); Johnson, C. C.; Barber, P. W.; Massoudi, H.; Iskander, M. F.; Allen, S. J.; Mitchell, J. C. *Radio Sci* 14(6S): 5-7; 1979 (14 refs).

The second edition of the *Radiofrequency Radiation Dosimetry Handbook* is described. This second edition extends the data contained in the first edition that was published by the USAFSAM in September 1976. Several additional techniques have been used to extend the frequency range over which the specific absorption rate or mass-normalized rate of energy absorption (SAR) is calculated for models of human beings and animals, resulting in useful theoretical data over the frequency range of 10 kHz-100 GHz. However, data contained in the second edition are still limited to whole-body average SARs in homogeneous models; information about distributive SARs is not given. The second edition also contains data on groundplane effects, scattering, and thermal response along with a summary of theoretical approaches and experimental data found in the literature.

6552 NEAR-ZONE FIELD-STRENGTH METER FOR MEASUREMENT OF RF ELECTRIC FIELDS. *(Eng)* Eggert, S. (Central Inst. Industrial Medicine, Noldnerstr. 40-42, 1134 Berlin, E. Germany); Goltz, S.; Kupfer, J. *Radio Sci* 14(6S): 9-14; 1979 (5 refs).

A near-zone field-strength meter that covers the frequency range of 60 kHz to 350 MHz is described. The meter utilizes two dipole probes. One, a double-T probe, covers the frequency range of 60 kHz to 30 MHz and measures field-strengths ranging from 3-2,500 V/m. The other probe, a double-cone type, covers the frequency range of 10-350 MHz and measures field-strengths ranging from 1.5-1,250 V/m. Accuracy of measurement, temperature range, and response time of the near-zone field-strength meter are ±20%, -10 C to +40 C, and 1 sec, respectively. The power supply consists of two 9-V batteries or two 8.4-V nickel-cadmium accumulators. Total weight of the instrument is 2 kg. One probe measures 630 by 140 mm, and the second probe measures 630 by 50 mm. The indicating meter measures 180 by 86 by 100 mm. For calibrating the probes, a calibrating stand based on the principle of a parallel-plate capacitor is used in the frequency range from 60 kHz to 18 MHz, and a triplate-stripline (TEM-cell) is used in the frequency range of 10-350 MHz. Owing to the high sensitivity of the probes and the good local selectivity of complicated field configurations according to intensity and direction, the near-zone field-strength meter is suited for optimizing shielding devices and for checking their efficiency. The probe has also proved useful in experiments with animals, e.g. for determining the degree of homogeneity of electrical fields in exposure chambers.

6553 PART-BODY AND MULTIBODY EFFECTS ON ABSORPTION OF RADIO-FREQUENCY ELECTROMAGNETIC ENERGY BY ANIMALS AND BY MODELS OF MAN. *(Eng)* Gandhi, O. P. (Dept. Electrical Engineering and Bioengineering, Univ. Utah, Salt Lake City, UT 84112); Hagmann, M. J.; D'Andrea, J. A. *Radio Sci* 14(6S): 15-21; 1979 (10 refs).

Numerical solutions based on an improved model of man have demonstrated that the deposition of radio frequency energy at supraresonant frequencies is attributable to resonance of body parts. For head resonance, which occurs near 350 MHz in man, the absorptive-cross section is nearly three times the physical cross-section of the head. The arm has a prominent resonance at 150 MHz. Numerical solutions, antenna theory, and experimental results with animals have shown that energy deposition is altered by multibody effects. A maximum of about 50% enhancement in the specific absorption rate (SAR) is found with two bodies, but significantly greater enhancement is possible with three or more bodies, with interbody spacing being critical. Antenna theory and an observed $1/f$ dependence at supraresonant frequencies have been used to develop empirical equations for the whole-body SAR for models of man and for laboratory animals with the vector of the electric field parallel to the body's long axis. The empirical SAR values are in good agreement with the experimental values obtained for several animal species.

6554 NUMERICAL CALCULATION OF ELECTROMAGNETIC ENERGY DEPOSITION IN MODELS OF MAN WITH GROUNDING AND REFLECTOR EFFECTS. *(Eng)* Hagmann, M. J. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Gandhi, O. P. *Radio Sci* 14(6S): 23-29; 1979 (10 refs).

Image theory was used to obtain moment-method solutions of the deposition of electromagnetic energy (10-200 MHz) in standard man as a function of grounding and reflector effects so that all calculations were limited to a perfectly conducting ground plane or to reflectors with an infinite extent. The calculated resonant frequency of man standing on a ground plane was 47 MHz compared to 77 MHz for man in free space. The specific absorption rate (SAR) of man on the ground plane at the reduced resonant frequency was 32.5% greater than the SAR for man in free space at the free-space resonant frequency. The decrease in resonant frequency and alteration in energy deposition due to grounding may be explained by considering a double-length man in free space. If the model of man had a cross-section independent of height and a complex permittivity independent of frequency, the grounded resonant frequency would be 50% of the free-space resonant frequency; however, a ratio of 0.610 is obtained for the present model. The dependence of reflector effects on spacing and frequency are in agreement with the gain enhancement calculated for dipoles by antenna theory. The enhancement in energy deposition due

to reflector effects becomes small for small values of separation or for high frequencies, which effects agree with antenna theory only if finite width of the dipole is considered.

6555 MEASUREMENTS OF STRENGTHS OF ELECTRIC AND MAGNETIC FIELDS NEAR INDUSTRIAL RADIO-FREQUENCY HEATERS. *(Eng)* Hietanen, M. (Inst. Occupational Health, Haartmaninkatu 1, SF-00290 Helsinki 29, Finland); Kalliomaki, K.; Kalliomaki, P. L.; Lindfors, P. *Radio Sci* 14(6S): 31-33; 1979 (2 refs).

Electric and magnetic field strengths were measured near 35 plastic welding machines in Finland. All of the machines operated at a frequency of 27 MHz at nominal power outputs ranging from 0.5 to 35 kW. The magnetic and electric fields were measured in the area of the worker's head, chest, pelvis, and hands as well as 1 and 2 m from the electrodes. The maximal value of electric field strengths near the workers exceeded 200 V/m (100 W/m^2) in the case of 23 radio frequency devices (66%); the leakage from 30 devices exceeded the Finnish proposed safety standard of 60 V/m (10 W/m^2). The maximal value of the magnetic field exceeded 0.5 A/m (100 W/m^2) for 21 of the devices (60%); the proposed Finnish limit of 0.2 A/m (10 W/m^2) was exceeded by 26 devices.

6556 A GEOMETRICAL-OPTICS AND AN EXACT SOLUTION FOR INTERNAL FIELDS IN AND ENERGY ABSORPTION BY A CYLINDRICAL MODEL OF MAN IRRADIATED BY AN ELECTROMAGNETIC PLANE WAVE. *(Eng)* Massoudi, H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Johnson, C. C. *Radio Sci* 14(6S): 35-42; 1979 (23 refs).

Expressions for the specific absorption rate (SAR) in an infinitely long, lossy cylinder that is irradiated by a radio frequency plane wave are obtained for electric and magnetic polarizations both by an exact solution and by an approximation based on geometric optics. The calculated results for cylindrical models of standard man and rats of three different sizes are compared with those of prolate spheroidal models. Based on these comparisons, the following conclusions are reached: (1) For magnetic polarization, energy absorption characteristics of the cylindrical model are nearly the same as those of the prolate spheroidal model over all frequencies where prolate spheroid solutions are available, indicating that the infinite cylindrical model can be very useful in calculating the SAR. (2) For electric polarization, energy absorption characteristics in the cylinder have the expected behavior (based on experimental results) at frequencies only above resonance in spheroids and fit very well with the values calculated by the geometric-optics approximation, indicating that the cylindrical model can be useful for calculation of the SAR in a band that extends above resonant frequencies. For models of human beings, this frequency band is from about 400 MHz to 10 GHz. These new data allow meaningful interpolation of SAR data in the remaining frequency bands where calculations are still not possible, thus providing good estimates of SAR over the entire frequency range of interest for homogeneous models.

6557 ABSORPTION OF HIGHER-FREQUENCY RF ENERGY BY BIOLOGICAL MODELS: CALCULATIONS BASED ON GEOMETRICAL OPTICS. *(Eng)* Rowlandson, G. I. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112); Barber, P. W. *Radio Sci* 14(6S): 43-50; 1979 (17 refs).

A method based on geometric optics is outlined that enables calculation of energy absorption characteristics of prolate spheroidal models of biologic bodies at the high end of the radio frequency (RF) spectrum. The technique approximates the surface of the prolate spheroid by dividing the surface into small planar subareas. The angle of incidence, the values of the parallel and perpendicular components of the incident radiation with respect to the plane of incidence for each subarea, and the transmission coefficients for each component are determined, and the energy being transmitted into each subarea is then calculated. The transmitted energy is assumed to be completely absorbed due to the small depth of penetration of electromagnetic waves into lossy biologic bodies in the suprasonant region. The total energy absorbed is found by summing over all subareas. Validity testing with Mie theory in conjunction with consideration of the localization principle of geometric optics indicates that this technique is applicable to the model of man at frequencies >6 GHz. Computer-generated results for a 70-kg prolate spheroidal model of man indicate the following: the dependence of energy absorption on the incident wave's polarization and angle of incidence is markedly different from dependencies observed at lower frequencies; the rate of energy absorption increases with frequency within the asymptotic limit; and the use of simple planar models is inadequate to determine energy absorption characteristics of biologic bodies at high RF frequencies. The primary utility of these results is that they provide asymptotes to which previously calculated low-frequency results can be related.

6558 HEATING OF SPHERICAL VERSUS REALISTIC MODELS OF HUMAN AND INFRAHUMAN HEADS BY ELECTROMAGNETIC WAVES. *(Eng)* Rukspollmuang, S. (Dept. Electrical Engineering and Systems Science, Michigan State Univ., East Lansing, MI 48824); Chen, K. M. *Radio Sci* 14(6S): 51-62; 1979 (9 refs).

A numerical method based on a tensor integral equation was used to quantify the induced elec-

tromagnetic (EM) heating in realistic models of the human and infrahuman head and in spherical models of human and infrahuman heads and brains at frequencies of 918 and 2,450 MHz. The realistic model of the human head consisted of a brain of realistic shape and eyes that were surrounded by a bony structure. The EM heating induced in the brain of the realistic model was significantly lower than that induced in the brain of the spherical model. The surrounding bony structure tended to attenuate the induced EM heating of the brain and eyes. Calculations for a 918-MHz plane wave with a vertically polarized electric field of 1 V/m indicated that the rate of dissipation of energy in a realistic model of the uncovered brain was 4.591 x 10^{-n} W, which was about 43% higher than that for the brain encased in its bony structure. The induced EM heating of the eyes was relatively low compared with that in the surrounding bony structure.

6559 CIRCULARLY POLARIZED 2450-MHz WAVEGUIDE SYSTEM FOR CHRONIC EXPOSURE OF SMALL ANIMALS TO MICROWAVES. *(Eng)* Guy, A. W. (Dept. Rehabilitation Medicine RJ-30, Bioelectromagnetics Res. Lab., Univ. Washington Sch. Medicine, Seattle, WA 98195); Wallace, J.; McDougall, J. A. *Radio Sci* 14(6S): 63-74; 1979 (3 refs)

A system originally designed for chronic exposure of large numbers of small animals to 918-MHz microwaves was modified to permit exposure at 2,450 MHz. The modified system makes use of the original 918-MHz wire-mesh waveguide but with the feed probes and hybrid rings removed. Plastic chambers for housing small animals (maximum body mass of 800 g) are used as originally designed. Circular polarization of the 2,450-MHz field is provided by a retrofitted 2,450-MHz waveguide with a built-in circular polarizer; the original wire-screen waveguide is terminated in a retrofitted 2,450-MHz waveguide that contains two probes attached to 50-ohm coaxial terminations. The modified system can operate at either 918 MHz or 2,450 MHz, depending on whether the original probes or the retrofitted waveguide sections are used. The same water supply, consisting of a standard water bottle and a glass nozzle that are electrically decoupled from the animal by two concentric one-quarter wavelength coaxial choke sections, is still used, but with choke sections shortened to correspond to one-quarter wavelength at 2,450 MHz. Although the large-diameter exposure cell can support modes other than the dominant TE11 circular polarized mode, the system operates as satisfactorily as the original. Each animal may move freely within its chamber with minimal change in field coupling since the incident circularly polarized waves ensure that the animal is uniformly exposed by a propagating field, regardless of orientation and movement. The severe changes in coupling due to an animal's orientation with respect to field polarization that are observed in plane-wave exposure systems are virtually eliminated. The system allows easy quantitation of the averaged power density of energy incident on the animal and of the specific absorption rate (SAR) in the animal. Body distributions of SAR can be obtained by thermography on models and on cadavers of species selected for study. The voltage standing wave ratio in each cell is sufficiently low that any number of cells can be coupled to a single source through a power splitter without the need for an isolator.

6560 A MICROWAVE EXPOSURE SYSTEM FOR MARINE ANIMALS: DOSIMETRY AND REFLECTOMETRIC OBSERVATIONS. *(Eng)* McRee, D. I. (Natl. Inst. Environmental Health Sciences, P. O. Box 12233, Research Triangle Park, NC 27709); Wachtel, H. *Radio Sci* 14(6S): 75-79; 1979 (17 refs).

An aquatic system in which marine biota can be exposed under natural conditions for indefinite periods of time to dose-determinate levels of microwave radiation is described. A 2,450-MHz continuous wave microwave source is used to feed a standard-gain horn that radiates a glass-faced aquarium in the far field. The source and aquarium are located in a microwave-anechoic chamber. Seawater in the 95-l aquarium can be maintained at the desired temperature by a high-capacity heat-exchange system. By caging sets of one or more small aquatic animals at various distances from the glass face, determinate specific absorption rates (SARs) at different levels can be achieved simultaneously within the aquarium. Reflectometric data on a small marine animal, the mollusc *Aplysia californica*, indicated that the microwave absorption properties of this animal are approximately the same as those of seawater. Since the SAR at a given location in the seawater was almost the same as that measured inside an *Aplysia* at the same location, it can be assumed that little or no reflections occur within the aquarium and that the animals do not cast absorption shadows over one another. Therefore, by knowing the SAR at the surface of the seawater, SARs at more distal locations can be computed irrespective of the number of animals or their location in the aquarium. This system should prove useful in studying effects of long-term microwave exposures in animals that are otherwise maintained in a natural environment.

6561 THE NONMETALLIC THERMOCOUPLE: A DIFFERENTIAL-TEMPERATURE PROBE FOR USE IN MICROWAVE FIELDS. *(Eng)* Olsen, R. G. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508); Molina, E. A. *Radio Sci* 14(6S): 81-84; 1979 (6 refs).

A nonmetallic temperature probe that is suitable for use in microwave dosimetry over a wide range of temperatures is described; the probe can be made of commercial, readily available materials. The sensor

element is a thermocouple junction composed of dissimilar nonmetallic conductors. The conductors themselves, although not entirely lossless, are readily available carbon-loaded materials such as conductive silicone or conductive fluorocarbon. Secondary thermocouple junctions are formed where metallic leads attach to the nonmetallic conductors. The voltage output from the device is, for certain temperature ranges, proportional to the temperature difference between the primary and secondary junctions. An instrumentation amplifier is described that boosts the output of the probe and eliminates much 60-Hz interference. Tracking accuracy of the nonmetallic thermocouple (NMT) with the secondary junctions thermally insulated is within 0.1 C. Comparative dosimetric data indicate that the NMT produces results that compare favorably with those obtained by other, much more expensive, probes. The repeatability and long-term stability of the NMT appear to be very good, with no change observed in output sensitivity during more than 12 mo of periodic testing. Probe-to-probe voltage/temperature characteristics have typically been within 1% of each other for six probes made with commercially available, conductive carbon/fluorocarbon and carbon/silicone conductors. Use of the NMT in the laboratory requires that the probe be stationary to avoid noise pick-up.

6562 ACTIVITY OF MEMBRANE-BOUND ENZYMES EXPOSED TO SINUSOIDALLY MODULATED 2450-MHz MICROWAVE RADIATION. *(Eng)* Allis, J. W. (Experimental Biology Div., Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711); Fromme, M. L. *Radio Sci* 14(6S): 85-91; 1979 (22 refs).

The activity of membrane-bound enzymes that were irradiated with 2,450-MHz microwaves (specific absorption rate of 26 mW/g) sinusoidally modulated at 16, 30, 90, and 120 Hz was investigated by spectrophotometry with the temperature controlled at 25 ± 1.0 C. Cytochrome oxidase and adenosine triphosphatase (ATPase) were isolated and prepared from rat tissue. Immediately after initiation of enzymatic activity, irradiation was begun and continued for several minutes while the reaction rate was monitored. Cytochrome oxidase activity was measured directly by monitoring the change in absorbance of its substrate, cytochrome c, at 550 nm. Activity of ATPase was measured by a coupled-enzyme system in which the rate of conversion of adenosine triphosphate to adenosine diphosphate was followed at 340 nm by stoichiometric oxidation of reduced nicotinamide adenine dinucleotidephosphate. Pyruvate kinase and lactate dehydrogenase, which performed the intermediate steps, were always present in excess so that the ATPase activity was rate controlling. No statistically significant differences in enzyme activities were obtained between irradiated and control samples at any of the modulation frequencies for either enzyme system.

6563 INDUCTION OF CALCIUM-ION EFFLUX FROM BRAIN TISSUE BY RADIO-FREQUENCY RADIATION: EFFECTS OF MODULATION FREQUENCY AND FIELD STRENGTH. *(Eng)* Blackman, C. F. (Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711); Elder, J. A.; Weil, C. M.; Benane, S. G.; Eichinger, D. C.; House, D. E. *Radio Sci* 14(6S): 93-98; 1979 (28 refs).

The effects of modulation frequency and incident power density on radio frequency radiation-induced calcium ion efflux from chick brain tissue in vitro were studied. The forebrains of 1- to 4-day-old chicks (*Gallus domesticus*), separated at the midline to provide treatment-control pairs, were labeled in vitro with radioactive calcium. Samples of tissue were exposed for 20 min in a rectangular strip transmission line (Crawford cell) to 147-MHz radiation that was amplitude modulated sinusoidally at selected frequencies between 3 and 30 Hz. Power densities of incident radiation ranged between 0.5 and 2.0 mW/cm^2. Comparison with nonirradiated samples revealed a statistically significant ($p<0.01$) increase in calcium ion efflux (24%) in irradiated samples at a modulation frequency of 16 Hz and at a power density of 0.75 mW/cm^2. These data confirm the existence of a frequency window as well as a narrow power density window within which calcium ion efflux is enhanced.

6564 MICROWAVE IRRADIATION AND LIPID METABOLISM IN MICE. *(Eng)* Deficis, A. (Centre d'etudes et de recherches de Toulouse, Office National d'Etudes et de Recherches Aerospatiales, 2, avenue Ed Belin, B.P. 4025, 31055 Toulouse Cedex, France); Dumas, J. C.; Laurens, S.; Plurien, G. *Radio Sci* 14(6S): 99-101; 1979 (6 refs).

One hundred and fifty-four male DBA mice (with 126 sham-irradiated controls, 2-mo-old) were exposed for nearly 60 hr over a 3-day period to 2.45-GHz continuous wave microwaves in either multimode cylindrical cavities (power density, 3.3 ± 2.2 mW/cm^2) or in an electrically anechoic chamber (power density, 4 ± 2 mW/cm^2). Two hours after the termination of irradiation, the mean serum triglyceride level of mice irradiated in cavities was 1.65 ± 0.11 g/l versus a control mean of 1.27 ± 0.08 g/l ($p<0.001$). A similar increase was noted in mice exposed in the anechoic chamber, mean 2.08 ± 0.08 g/l versus a control mean of 1.34 ± 0.09 g/l ($p<0.001$). Levels of beta-lipoproteins were also elevated reliably in irradiated mice. Those exposed in cavities had a mean serum level of 3.79 ± 0.32 g/l versus a control mean of 2.70 ± 0.20 g/l. Those exposed in the anechoic chamber had a mean serum level of 4.26 ± 0.34 g/l versus a control mean of 2.83 ± 0.22 g/l. Although mean values for rectal temperature did not differ reliably among sham-, cavity-, and plane-wave-irradiated mice, there is little doubt that significant microwave absorption occurred in the mice. Effects of resonant absorption, however, should be considered when evaluating energy absorption in mice.

6565 EXTREMELY-LOW-FREQUENCY FIELDS AND THE SLIME MOLD *PHYSARUM POLYCEPHALUM*: EVIDENCE OF DEPRESSED CELLULAR FUNCTION AND OF INTERNUCLEAR INTERACTION. *(Eng)* Greenebaum, B. (Div. Science, Univ. Wisconsin-Parkside, Kenosha, WI 53141); Goodman, E. M.; Marron, M. T. *Radio Sci* 14(6S): 103-107; 1979 (12 refs).

Cultures of the acellular slime mold *Physarum polycephalum* were exposed continuously to 75-, 60-, and 45-Hz continuous wave and 76-Hz frequency-modulated fields for periods ranging from 2 mo to 5 yr at electric field intensities ranging from 0.04 to 0.7 V/m (root mean square) and magnetic field intensities ranging from 0.01 to 0.2 millitesias (root mean square). In general, a slowing of cellular processes was observed. A longer nuclear division cycle and depressed respiration rate were seen under exposure to most continuous wave fields and all frequency-modulated fields. Lengths of the nuclear division cycle of cultures formed by mixing exposed and control cultures measured between those of control and exposed cultures. Indirect measurements of chromosomal numbers of this polyploid organism indicated no statistically significant difference between exposed and control nuclei.

6566 EFFECTS OF MICROWAVE RADIATION ON ERYTHROCYTE MEMBRANES. *(Eng)* Liu, L. M. (Dept. Biophysics, Medical Coll. Virginia, Richmond, VA 23298); Nickless, F. G.; Cleary, S. F. *Radio Sci* 14(6S): 109-115; 1979 (9 refs).

The effects of microwave irradiation on the permeability and osmotic fragility of mammalian erythrocyte membranes were investigated and compared to the effects of conventional heating. Suspensions of rabbit, human, and dog red blood cells (RBC) were irradiated by S-band microwaves in a WR-284 waveguide chamber for a period of either 20 min or 3 hr at power densities of 10-58 mW/cm^2 and at absorption rates of 22-200 mW/g. Potassium ion and hemoglobin release and the osmotic fragility of the RBC were assayed. Conventional heating and microwave radiation resulted in sample temperatures that ranged from 25 to 44 C. There were no statistically significant differences between freshly prepared cells that were irradiated and those that were heated in a temperature-controlled water bath at energy absorption rates near 200 mW/g for 3-hr exposures at a frequency of 3.0 GHz or at energy absorption rates near 80 and 100 mW/g for frequencies of 2.45 and 3.95 GHz, respectively. Freshly prepared suspensions of rabbit RBC and ouabain-treated suspensions were also exposed to 3.0-GHz microwaves at an absorption rate of 170 mW/g for 20 min or 3 hr. No statistically significant differences were detected between irradiated and water-bath-heated samples. In addition, the effects of 3.0-GHz microwaves on rabbit RBC that had been held for 7 days at 4 C prior to 3 hr of exposure were studied at absorption rates as high as 170 mW/g; no statistically significant effects of microwave irradiation were observed compared with water-bath-heated controls, although both modes of heating induced permeability changes relative to room temperature controls.

6567 COMPARATIVE EFFECTS OF WATER-BATH- AND MICROWAVE-INDUCED HYPERTHERMIA ON SURVIVAL OF CHINESE HAMSTER OVARY (CHO) CELLS. *(Eng)* Livingston, G. K. (Dept. Pediatrics, Univ. Utah, Salt Lake City, UT 84132); Johnson, C. C.; Dethlefsen, L. A. *Radio Sci* 14(6S): 117-123; 1979 (19 refs).

The possible extrathermal effect of 2,450-MHz continuous wave microwave radiation was investigated by subjecting suspensions of asynchronous Chinese hamster ovary (CHO) cells in the log phase of growth to equivalent thermal stress (44 C for 60 min) by microwave radiation and by heating in a water bath. Microwave energy was intermittently applied to the long dimension of a plastic culture tube that was inserted into a waveguide parallel to the electric field vector. Temperature-rise profiles of the two hyperthermic treatments were matched by monitoring suspensions of cells with a liquid crystal fiberoptic temperature probe. Immediately after hyperthermia, the cells were equilibrated at 37 C, counted, and plated out for colony assays to quantitate cell survival. Intrasample uniformity of heating and accurate thermometry were highly critical to the demonstration of parity in the experiment, since temperature variations of only 1 C in suspensions of relatively small volume can have a profound effect on cell survival.

6568 A METHOD FOR THE STUDY OF RETINAL GANGLION CELL ACTIVITY INDUCED BY ELF MAGNETIC FIELDS. *(Eng)* Lovsund, P. (Dept. Medical Engineering, Linkoping Univ., S-581 85 Linkoping, Sweden); Oberg, P. A.; Nilsson, S. E. *Radio Sci* 14(6S): 125-126; 1979 (1 ref).

A method for recording the electrical activity of frog retinal ganglion cells after exposure to a magnetic field is described. The frog (*Rana temporaria*) retina is dissected free and is placed in a thermostated holder containing Ringers solution. A glass microelectrode is positioned in the ganglion cell layer. By means of an optical system, a light spot is projected on the retina and the off-cells (which respond when light is switched off) are identified. When an off-cell has been localized with the electrode, the retina is exposed to a magnetic field at frequencies ranging from 10 to 50 Hz and at magnetic flux densities of 0 to 30 millitesla. The amplified signal is recorded on a tape recorder. When the magnetic field is switched off, electrical activity from the retinal ganglion cells can be recorded for a period of about 15 sec. Thus, a direct influence of low-frequency

magnetic fields on excitable cells of the retina can be shown. The response of ganglion cells varies with the properties of the magnetic field. The response also differs from that obtained by stimulation with broad-spectrum light. This method opens up new possibilities to study at the cellular level the influence of an electromagnetic field on excitable tissue.

6569 **MODELS OF LONG-RANGE ORDER IN CEREBRAL MACROMOLECULES: EFFECTS OF SUB-ELF AND OF MODULATED VHF AND UHF FIELDS.** *(Eng)* Sheppard, A. R. (Jerry L. Pettis Memorial VA Hosp., Loma Linda, CA 92357); Bawin, S. M.; Adey, W. R. *Radio Sci* 14(6S): 141-145; 1979 (31 refs).

Calcium efflux from isolated chick brain exposed for 20 min to 16-Hz sinusoidally modulated radio frequency radiation (450 MHz) was increased by about 10% at power levels of 0.1 and 1.0 mW/cm². However, calcium efflux was not significantly changed at a lower power level of 0.05 mW/cm² or at higher power levels of 2.0 and 5.0 mW/cm². These data substantiate the upper and lower bounds for a power window in the effect on calcium efflux, which is in addition to the previously described frequency window. The theoretical understanding of weak-field effects in brain tissue is incomplete, but a model encompassing the unique low-frequency dielectric properties of cells, the extensively branched anionic residues found on cellular glycoproteins, and the postulated cooperative behavior of membrane macromolecules provides an understanding of how and where the transduction of weak oscillatory fields may occur.

6570 **PERINATAL EXPOSURE OF RATS TO 2450-MHz CW MICROWAVE RADIATION: EFFECTS ON LYMPHOCYTES.** *(Eng)* Smialowicz, R. J. (Experimental Biology Div., Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711); Kinn, J. B.; Elder, J. A. *Radio Sci* 14(6S): 147-153; 1979 (22 refs).

The effect on rat lymphocyte function of perinatal exposure to 2,450-MHz continuous wave microwave radiation was investigated. Rats were irradiated at a power density of 5 mW/cm² in utero from day 6 of gestation through 40-41 days of age for 4 hr/day, 7 days/wk in a temperature- and humidity-controlled environment under far-field conditions in an electrically anechoic chamber. An equal number of sham-exposed rats that were maintained under the same environmental conditions served as controls. Specific absorption rates (SAR, determined by twin-well calorimetry) for rats of different ages ranged from 0.7 to 4.7 mW/g; these SAR values were less than the basal metabolic rates of rats of comparable mass and age. At 20-21 and 40-41 days of age, rats were bled and complete blood cell counts were done. In addition, in vitro blastogenesis of blood and lymph node lymphocytes was measured by ^{3}H-thymidine incorporation into deoxyribonucleic acid following stimulation of cells with thymus-derived (T)- and bone marrow-derived (B)-lymphocyte mitogens. There were significant increases in the mitogen-stimulated response of both T- and B-lymphocytes from irradiated rats in comparison with sham-irradiated controls. There were no consistent changes, however, in peripheral blood cell counts after exposure to 2,450-MHz microwaves. These results indicate that long-term exposure of rats in utero and through early life may result in increased response of lymphocytes to stimulation with mitogens in vitro.

6571 **CONTRACTION OF SMOOTH MUSCLE IN A MICROWAVE FIELD.** *(Eng)* Whitcomb, E. R. (Experimental Biology Div., Health Effects Res. Lab., Environmental Res. Center, EPA, Research Triangle Park, NC 27711); Blackman, C. F.; Weil, C. M. *Radio Sci* 14(6S): 155-158; 1979 (7 refs).

Spontaneous contractions of smooth muscle were studied during microwave irradiation of isolated gut segments of adult male albino Sprague-Dawley rats that were exposed to 1-GHz continuous wave radiation by means of a capacitive-plate exposure system. For stabilization, the gut segment was maintained initially at a temperature of 7 C for 1 hr and then at 36 C for 1 hr in a modified Ringer's solution prior to irradiation. During the recording of contractions the gut segment was suspended in a 10-ml plastic tube and was bathed by Ringer's solution (pH 7.5) at 36 C at a flow rate of 6 ml/min from a 500-ml reservoir. Contractions were measured by a strain gauge. Frequency distributions of 500 contractions each were made before and during a single exposure and were displayed as interval-histogram patterns. Four gut preparations were exposed to each of the following specific absorption rates (SAR): 1.2, 2.3, and 6.9 mW/g. For each SAR the response patterns for the four gut preparations representing a before-exposure (control) condition were summed and compared with the summed response patterns of the same preparations during exposure. No effect of microwave irradiation on the rate of spontaneous contractions of smooth muscle was observed.

6572 **THE EFFECT OF LOW-LEVEL 2,450-MHz CW MICROWAVE RADIATION AND BODY TEMPERATURE ON EARLY EMBRYONIC DEVELOPMENT IN CHICKENS.** *(Eng)* Fisher, P. D. (Surgical-Medical Res. Inst., Univ. Alberta, Edmonton, Alberta, Canada T6G 2N8); Lauber, J. K.; Voss, W. A. *Radio Sci* 14(6S): 159-163; 1979 (8 refs).

The effects of 2,450-MHz continuous wave microwave radiation (mean incident density, 3.46 ± 1.45 mW/cm²) on cranial length and wet mass of 4- and 5-day-old

chick embryos (*Gallus gallus*) at different incubation temperatures (32-36 C) were investigated. A temperature-dependent effect on growth rate was observed. At 36 C, final cranial lengths and wet mass of experimental embryos were below those of controls after 4 and after 5 days of incubation; however, the growth rate of irradiated embryos was higher than that of controls. At 32 C, the final values of cranial length and wet masses were higher for irradiated embryos than for control embryos after 4 and after 5 days of incubation, while the growth rate of irradiated embryos was lower than that of controls. After comparing wet mass data with cranial length data, it is concluded that the developmental rate of the whole embryo was affected and that the effect was a result of some mechanism not associated with an incremented temperature of the embryo.

6573 INTENSITY OF MICROWAVE IRRADIATION AND THE TERATOGENIC RESPONSE OF *TENEBRIO MOLITOR. (Eng)* Green, D. R. (Dept. Electrical Engineering, Box 1127, Washington Univ., St. Louis, MO 63130); Rosenbaum, F. J.; Pickard, W. F. *Radio Sci* 14(6S): 165-171; 1979 (11 refs).

Pupae (1st day) of *Tenebrio molitor* were individually irradiated for 2 hr by 9.0-GHz continuous wave microwaves in an X-band waveguide (TE-10 mode) at fixed power levels of incident radiation that ranged from 10 to 320 mW (estimated dose rates of approximately 25-800 mW/g). Subsequent examination of adults for gross structural abnormalities revealed that the occurrence of defects was a complex function of power level of incident radiation. As the level was increased from 10 to 80 mW, the incidence of defects first increased and then decreased; above 80 mW, the incidence of defects increased once more. The probability of pupal mortality increased only in the power level region above 80 mW. Neither intact (ideal) nor structurally defective (nonideal) pupae exhibited much evidence of teratogenesis at 80 mW; otherwise, ideal pupae were more resistant to insult at radiation levels ranging from 20 to 320 mW. The data indicate that these teratogenic effects represent a putatively nonthermal phenomenon most readily seen under conditions of low relative humidity.

6574 EFFECTS OF REPEATED EXPOSURE TO 148-MHz RADIO WAVES ON GROWTH AND HEMATOLOGY OF MICE. *(Eng)* Lin, J. C. (Dept. Electrical and Computer Engineering, Wayne State Univ., Detroit, MI 48202); Nelson, J. C.; Ekstrom, M. E. *Radio Sci* 14(6S): 173-179; 1979 (9 refs).

Mice were exposed to 0.5 mW/cm² of 148-MHz radio frequency energy (specific absorption rate of 0.013 mW/g) in a transverse electromagnetic mode exposure chamber for 1 hr/day, 5 days/wk for 10 wk beginning on the 4th to 7th day postpartum to study the effects of repeated exposures to radio waves on murine growth and hematology. The mice were weighed daily from the beginning of radiation exposure for the 10-wk exposure period and then weekly thereafter. Blood was drawn from the tail vessels for analysis at 28, 70, 100, 250, 300, 360, and 600 days of age. Mean body mass was comparable in both radio frequency-irradiated mice and sham-irradiated controls. The formed elements in the blood were also unaffected by exposure to the low-level very high frequency fields.

6575 DEVELOPMENTAL EFFECTS OF MICROWAVES ON *TENEBRIO*: INFLUENCES OF CULTURING PROTOCOL AND OF CARRIER FREQUENCY. *(Eng)* Pickard, W. F. (Dept. Electrical Engineering, Washington Univ., St. Louis, MO 63130); Olsen, R. G. *Radio Sci* 14(6S): 181-185; 1979 (8 refs).

First-day pupae of the darkling beetle *Tenebrio molitor* from an in-house colony and from an outside supplier were exposed to continuous wave microwaves in the far field of a horn-irradiated, temperature-controlled, anechoic chamber. Both experimental and control pupae were allowed to develop to the adult stage and were then examined for the presence of gross morphologic abnormalities. Control pupae from the in-house colony developed significantly fewer developmental abnormalities than did control pupae purchased from the outside supplier. A first series of experiments was performed at a frequency of 5.95 GHz. When pupae were held parallel to the electric field vector for 2 hr at an electric field maximum of 91 V/m root mean square (RMS) of a standing wave distribution and were exposed at a nominal dose rate of 130 W/g, no effect was observed in in-house pupae or in outside pupae. When pupae were held parallel to the magnetic field vector for 2 hr at a magnetic field maximum of 1.53 A/m RMS of a standing wave distribution and were exposed at a nominal dose rate of 54 W/kg, no effect was seen in colony pupae; significant effects were observed in cultures of the other pupae. When only outside pupae were held parallel to the electric field vector in a traveling wave distribution at 110 W/m², no effect was detected for 13-hr exposures. In a second series of experiments, a frequency of 10.025 GHz was used. When pupae were held antiparallel to Poynting's vector for 4 hr in a traveling wave field at 50 W/m², no effect was detected in colony pupae, while a marginally significant effect was observed in the outside pupae. For both pupal types the conditions maintained during pupal development had a significant effect on the incidence of abnormalities in the adults. Although it was not possible to stabilize the experimental system adequately enough to obtain consistently reproducible results, the data presented suggest the existence of a teratogenic effect of microwaves.

6576 MICROWAVE-INDUCED HYPERTHERMIA AND THE VISUALLY EVOKED ELECTROCORTICAL RESPONSE OF THE GUINEA PIG. *(Eng)* Bruce-Wolfe, V. (Dept. Psychiatry, Univ. Kansas Medical Center, Kansas City, KS 66103); Justesen, D. R. *Radio Sci* 14(6S): 187-191; 1979 (17 refs).

Five 3-mo-old female guinea pigs were observed during eleven experiments for visually evoked electrocortical responses (VERs) to a hyperthermic dose of 2,450-MHz microwave radiation. The microwave energy was electrically modulated as a bottom-clipped half-wave sinusoid at 60 Hz and was applied at a dose rate of 30-40 mW/g. The exposure durations ranged from 4.0 to 15.0 min (average 8.5 min). Latency of the N1 component of the VER, an inverse index of conduction velocity of primary visual fibers, was recorded within minutes of microwave exposure via an electroencephalograph on a signal-averaging computer. Cortical and rectal temperatures were observed and recorded during measurement of VERs. The mean latency from the onset of photic stimulation to the N1 peak diminished from 42.8 to 37.7 msec at respective cortical temperatures of 37.0 and 40.5 C, representing a mean increase of conduction velocity of 3.4%/C. A comparison of cortical and rectal temperatures during baseline measures revealed a mean difference of 1.96 ± 0.14 C, with rectal temperatures invariably higher. An analysis of cortical temperatures as a function of rectal temperature across sessions for all subjects after microwave-induced hyperthermia indicated that cortical temperatures fell to baseline at a slightly more rapid rate than did rectal temperatures. A rectal temperature of 44.0 C was associated with mortality in four of five animals studied.

6577 MICROWAVE-INDUCED AUDITORY RESPONSES IN GUINEA PIGS: RELATIONSHIP OF THRESHOLD AND MICROWAVE-PULSE DURATION. *(Eng)* Chou, C. K. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, RJ-30, Univ. Washington Sch. Medicine, Seattle, WA 98195); Guy, A. W. *Radio Sci* 14(6S): 193-197; 1979 (10 refs).

Auditory brainstem-evoked electrical responses of guinea pigs were used to determine microwave energy thresholds for perception of pulsed 918-MHz microwaves (30 pulses/sec, 10-500 μsec pulse duration) that were fed into a circular waveguide partially enclosing the animal's head. The peak and average incident power densities ranged from 62.4 to 156.0 mW/cm² and from 46.8 to 1,404.0 μW/cm², respectively. The incident energy density per pulse ranged from 1.56 to 46.80 μJoules(J)/cm², and the average absorbed energy density per pulse ranged from 5.99 to 179.64 mJ/kg. The peak of power density decreased as the pulse width increased to 30 μsec. Above 30 μsec, the threshold of peak power increased and then reached a constant value for pulses longer than 70 μsec. When plotted in terms of average density of absorbed energy, the threshold increased monotonically for pulses longer than 30 μsec. Overall, it was shown that the threshold of microwave hearing was related to the incident energy per pulse for pulses shorter than 30 μsec and to the peak power of incident energy for longer pulses, at least to 500 μsec. The threshold dependence on pulse width is consistent with predictions of the thermal-expansion theory. In conjunction with data on the microwave-induced cochlear microphonic, all of the evidence indicates that microwave hearing is the result of a thermoelastic mechanical disturbance.

6578 QUANTITATIVE DETERMINATION OF THRESHOLDS OF MAGNETOPHOSPHENES. *(Eng)* Lovsund, P. (Dept. Medical Engineering, Linkoping Univ., S-581 85 Linkoping, Sweden); Oberg, P. A.; Nilsson, S. E. *Radio Sci* 14(6S): 199-200; 1979 (3 refs).

Threshold values for the appearance of magnetophosphenes were determined in human volunteers exposed to a magnetic field under a variety of conditions. The magnetic field generator consisted of a sine-wave generator, a frequency counter, and a power amplifier that fed an electromagnet that was placed over the temples of the volunteers. Visually normal volunteers were exposed to a magnetic field at frequencies of 10-50 Hz and at flux densities of 0-40 milliteslas (mT). Threshold values of magnetophosphenes at each of several magnetic flux densities in steps of 5 Hz were determined in virtual darkness or with a white-background light at various luminance levels. In another series of experiments, discrete colors, which were generated by means of interference filters at transmission wavelengths of 443, 531, and 572 nm, were used for background illumination at a constant luminance level. A similar investigation under a colored background was performed with a group of color-defective volunteers (deuteranopes). Maximum sensitivity to magnetophosphenes induced by the magnetic field was observed in the frequency range of 20-30 Hz. Threshold values varied with the frequency of the magnetic field, the luminance level, and the spectral composition of the background light. Threshold values of color defectives were different from those of normal volunteers. A study of magnetophosphenes during a 30-min dark period of sensitization showed that the threshold values increased with increasing time in darkness. Some of the volunteers experienced after-images with a duration as long as 30 min, and some considered the experiment as unpleasant. The results of these experiments indicate that magnetophosphenes are generated in the retina. The differences between normal and color-defective volunteers probably reflect differences at the cellular level of the retina. The results also indicate that an externally applied magnetic field of low frequency may be valuable as a means of studying cellular functions in the retina. It

is also clear that magnetophosphenes are generated at magnetic flux densities of the same order of magnitude as those found in the welding and steel industry.

6579 CLASSICAL CONDITIONING OF MICROWAVE-INDUCED HYPERTHERMIA IN RATS. *(Eng)* Bermant, R. I. (Dept. Psychology, Univ. Wisconsin, Waukesha, WI 53186); Reeves, D. L.; Levinson, D. M.; Justesen, D. R. *Radio Sci* 14(6S): 201-207; 1979 (8 refs).

Twelve mature, experimentally naive, female albino Sprague-Dawley rats were randomly assorted into four equal groups and were subjected to classical conditioning procedures; the conditional stimulus (CS) was a 525-Hz auditory signal presented for 30-sec (habituation, 30 trials; conditioning, 200 trials; and extinction, 100 trials). A tone-only (TO) group that received the signal only for 30 sec served as controls. For rats in the three experimental groups, the CS antedated by 30 sec and then continued until cessation of the unconditional stimulus (US) during the conditioning phase. One of the experimental groups (tail-shock [TS] rats) received US in the form of a 2-sec application of 60-Hz alternating current to the tail at 300 V root mean square. Another group received 2,450-MHz sinusoidally modulated microwave (MW) irradiation for 10 sec that resulted in a dose rate of 420 mW/g. The third experimental group received the same type of MW irradiation for 30 sec at a dose rate of 220 mW/g. All three USs resulted in mean increments of colonic temperature (delta-T) approximating 1.5 C. During habituation and extinction phases, the CS was presented without the US to all animals. A conditional response (CR or "learned" hyperthermia) was demonstrated and was found to be highly resistant to extinction; however, it was also found to be a generalized reaction to the conditioning environment, although selective eliciting of CRs occurred outside the laboratory in the presence of the individual who trained the animals. The mean increments of conditionally elicited temperature were +0.37 C for the TS group, +0.5 C for the 30-sec MW group, and +0.7 C for the 10-sec MW group; although none of these delta-Ts differed reliably from each other, they all departed significantly from the negative delta-T for the TO controls (-0.47 C). It is concluded that hyperthermia, whether calorically induced by MW or the endogenous product of an external trigger, appears to be "learnable" and could be a source of experimental confounding of any thermally sensitive assay in which noxious stimuli are repeatedly presented to the psychologically intact organism.

6580 BEHAVIORAL SENSITIVITY OF A DOMESTIC BIRD TO 60-Hz AC AND TO DC MAGNETIC FIELDS. *(Eng)* Clarke, R. L. (Neuropsychology and Behavioral Radiology Lab., VA Medical Center, Kansas City, MO 64128); Justesen, D. R. *Radio Sci* 14(6S): 209-216; 1979 (32 refs).

Four Leghorn chickens (*Gallus gallus*), two cocks and two hens, were assessed for ability to perceive magnetic fields (0-Hz, direct current [DC] at 4.0 millitesla [mT]; 60-Hz alternating current [AC] at 1.7 mT root mean square) by a conditional emotional response. To test for modulatory imprinting, embryos received either a conventional incubation (2 animals) or were exposed during the 36-60th hr of a conventional incubation to 60-Hz sinusoidally modulated 2,450-MHz microwaves at an average dose rate of 100 ± 10 mW/g (2 animals). Each bird operantly responded for rewards of grain while being subjected to a Pavlovian conditioning procedure in which a 90-sec presentation of a magnetic field served as a conditional stimulus (CS) that terminated in a brief faradic shock to the feet, which served as the unconditional stimulus (US). Five to seven pairings of CS and US occurred aperiodically during daily 60-min sessions. A total of six ten-session blocks of formal testing was conducted, two blocks with the AC field, two with the DC field, and two with a sham field in which the US alone was presented to provide control baselines of responding. Neither mode of incubation nor gender was a reliable source of variation, but highly reliable changes ($p<0.01$) in the character of operant responding (e.g., increased variability) were observed during presentations of the AC or DC fields. The domestic fowl may therefore share a sensitivity to magnetic fields with several other avian species, although artifactual sensory cueing borne of vibration or heating of the magnetic field source may not be ruled out. If real, the birds' sensitivity to the nominal DC field was probably associated with behavioral modulation, with incessant movement in the field by a chicken, especially of its head, during the operant-respondent measures of conditioning. Based on these and other findings, it is suggested that detection of magnetic fields by avian species has its locus in the retina or in other neuroanatomical substrates of the visual system.

6581 OPERANT BEHAVIOR AND RECTAL TEMPERATURE OF SQUIRREL MONKEYS DURING 2.45-GHz MICROWAVE IRRADIATION. *(Eng)* de Lorge, J. (Naval Aerospace Medical Res. Lab., Naval Air Station, Pensacola, FL 32508). *Radio Sci* 14(6S): 217-225; 1979 (13 refs).

Four squirrel monkeys, *Saimiri sciureus*, were trained to respond on a two-level observing-response task for food pellets. After stable response rates developed, the monkeys (restrained in Styrofoam chairs) were exposed in an anechoic chamber to 2.45-GHz microwaves (far field) that were 100% amplitude (sinusoidally) modulated at 120 Hz at average power densities of 10-75 mW/cm^2. All four monkeys were exposed to irradiation for 30 min during 2-hr sessions, and three of these four were also exposed for 60 min during 2-hr sessions. No perma-

nent physical changes or changes in response level were observed in any of the animals following microwave irradiation. The behavior of the monkeys on the observing-response task was disrupted during either the 30- or 60-min exposures to microwave irradiation but only at power densities that were ≥50 mW/cm². This disruption was increasingly evident as power density increased. Under both durations of exposure, behavior was not consistently perturbed until rectal temperatures increased more than 1 C. Rectal temperature was slightly but reliably elevated at 10 mW/cm², was a monotonic function of the power density, and was markedly increased at power densities between 40 and 50 mW/cm². The information obtained in this study provides further support for constructing a scale of microwave-induced behavioral effects that is based on body mass. The power density threshold of behavioral effects in squirrel monkeys appears to be between 40 and 50 mW/cm² for a 1-hr exposure to 2.45-GHz energy. This threshold is 10-20 mW/cm² lower than that observed for the larger rhesus monkey on the same task.

6582 VIDEOTAPE OBSERVATION OF RATS AND MICE DURING AN EXPOSURE TO 2450-MHz MICROWAVE RADIATION. *(Eng)* Gage, M. I. (Health Effects Res. Lab., MD-74, EPA, Research Triangle Park, NC 27711); Berman, E.; Kinn, J. B. *Radio Sci* 14(6S): 227-232; 1979 (13 refs).

Videotape observations of rats and mice exposed to 2.450-MHz microwaves were performed to see if the animals would take behavioral action to minimize absorption of microwave energy by altering their orientation with respect to the electric field. Individual naive male CD rats were housed either in a cylindrical or in a cuboidal container, and male CD-1 mice were housed in a cuboidal container. They were placed in an anechoic chamber at temperatures of 22 or 28 C for a 1-hr pre-exposure period. During the 2nd hr, the animals were exposed to continuous wave microwave irradiation under far-field conditions at a power density of 15 mW/cm². Videotape samples of their positions were taken during a 2-hr session. Six rats and six mice were observed at each temperature level and were scored for orientation relative to the electric vector or to the magnetic vector of the microwave field. The results indicated that 2,450-MHz continuous wave microwaves did not cause the animals to alter their position from that adopted in response to environmental or caging conditions. The specific absorption rate (SAR) in rats was not dependent on their orientation in the field. The SAR in mice was dependent on their orientation in the field, but their orientation did not show changes interpretable as attempts to reduce microwave absorption.

6583 THE EFFECT OF PSYCHOACTIVE DRUGS ON OPERANT BEHAVIOR INDUCED BY MICROWAVE RADIATION. *(Eng)* Monahan, J. C. (Div. Biological Effects, BRH, FDA, PHS, HEW, 5600 Fishers Lane, Rockville, MD 20857); Henton, W. W. *Radio Sci* 14(6S): 233-238; 1979 (11 refs).

The effect of three different psychoactive drugs on microwave-induced operant behavior in the mouse was investigated. Five male CF1 mice were trained to escape from or to avoid 2.45-GHz continuous wave microwave radiation by emitting an operant response. The response consisted of an animal's interruption of a light beam passing through a conditioning chamber. If an animal responded while microwaves were on, radiation was terminated and remained off for 12 sec (an escape response). If an animal responded during the off period, each response (constituting avoidance) would reset a timer that delayed the onset of microwaves for another 12 sec. All responses involved discriminated cueing by a 2,900-Hz sonic stimulus that was paired with microwave irradiation. Averaged dose rates were 46 mW/g; the duration of irradiation varied with the subjects' escape-avoidance behavior. When stable baselines of responding were established, each subject was tested following the administration of each of three psychoactive compounds at various dosages: chlordiazepoxide (CDE)--1, 5, and 10 mg/kg; chloropromazine hydrochloride (CPH)--0.25, 0.5, and 1 mg/kg; and *d*-amphetamine sulfate (APS)--0.5, 1, and 2 mg/kg. Drugs were administered intraperitoneally 1x/wk, 15 min prior to a session, and in a random sequence across sessions. Treatment with CDE resulted in a decreased percent of avoidance responding coupled with an increased percent of escape responding. A substantial increase in the animals' cumulative exposure to microwaves was also noted when they were dosed with CDE. Data based on the administration of CPH and APS were highly variable both within and among subjects; thus, no conclusion was drawn regarding the effect of these drugs on microwave-induced escape and avoidance behavior.

6584 BEHAVIOR OF CHICKS EXPOSED TO LOW-POWER 450-MHz FIELDS SINUSOIDALLY MODULATED AT EEG FREQUENCIES. *(Eng)* Sagan, P. M. (Res. Service, 151, Jerry L. Petis Memorial VA Medical Center, Loma Linda, CA 92531); Medici, R. G. *Radio Sci* 14(6S): 239-245; 1979 (24 refs).

Twenty-four X-link Leghorn cockerel chicks (23-hr water-deprived, 8- to 12-day posthatch) were exposed for a 23-min period at power densities of 1 or 5 mW/cm² to 450-MHz fields amplitude modulated at 3 or 16 Hz while performing on a fixed-time (FT) 30-sec schedule of water reinforcement. Reinforcements were in no way dependent on the subject's behavior and were delivered every 30 sec for a 2-sec period. Sessions were divided into three 40-reinforcement epochs: the first and third epochs were used as control periods (the field was never presented), while the second epoch was that during which sham ex-

posures or exposures to the field occurred. Computer analyses of the recorded interim behavior revealed possible differences in the temporal distributions of motor activity as a function of the exposure condition; however, an analysis of variance performed on the mean latencies of activity counts showed that the differences were not statistically significant.

6585 SKILLED VISUAL-MOTOR PERFORMANCE BY MONKEYS IN A 1.2-GHz MICROWAVE FIELD. *(Eng)* Scholl, D. M. (U.S. Air Force Hosp., SGHMM, Elmendorf Air Force Base, Alaska 99506); Allen, S. J. *Radio Sci* 14(6S): 247-252; 1979 (27 refs).

Three young adult rhesus monkeys (*Macaca mulatta*) received three 120-min exposures (separated by 2-day intervals) of 1.2-GHz radio frequency radiation (RFR) at average power densities of 10 and 20 mW/cm², which resulted in respective specific absorption rates of 0.8 and 1.6 W/kg. The RFR (continuous wave) was centered on a subject's head with the electric field vector parallel to the horizontal plane of the cranium. The monkeys performed a compensatory visual-tracking task with alternating periods of work and rest of 1.5-min duration before and during exposure to RFR. During a work period, the task required continuous visual vigilance and skilled motor performance. The animals were motivated by mild electrical stimulation to maintain a circular cursor within the center 15% of an oscilloscopic display. The cursor was driven off this safe on-target area by a complex sinusoidal track that covered 40% of the display. Control data were used to establish 95% simultaneous confidence limits for the adjusted root mean square (ARMS) of tracking errors. The ARMS values from exposure sessions showed no decrement relative to control data. During the 36 hr of RFR, only 4 of 720 data points that were collected lay outside the confidence limits of control data, fewer than expected by chance. Strong evidence that RFR was not disruptive of behavior was observed despite approximate man-equivalent power densities of incident radiation of 24 and 48 mW/cm².

6586 MICROWAVE RADIATION AND DEXTROAMPHETAMINE: EVIDENCE OF COMBINED EFFECTS ON BEHAVIOR OF RATS. *(Eng)* Thomas, J. R. (Behavioral Sciences Dept., Naval Medical Res. Inst., Bethesda, MD 20014); Maitland, G. *Radio Sci* 14(6S): 253-258; 1979 (19 refs).

The combined effects of 2,450-MHz pulsed microwave (MW) radiation (2 μsec pulse duration, 500 pulses/sec) and dextroamphetamine (DAP) on the behavior of six male albino rats that performed on a temporal reinforcement schedule were investigated. During 1-hr sessions, only a response that was delayed by 18 sec or more after a preceding response was reinforced by a food pellet. A low and steady rate of responding was achieved after 13 wk of pretraining on the schedule. Initially, a dose-effect function was obtained in the absence of MW radiation for DAP doses ranging from 0.25 to 5.0 mg/kg. Smaller doses of DAP produced an increase in response rate with consequent reduction in the frequency of reinforcement. Maximal rates of responding occurred at DAP doses of 1.0-2.0 mg/kg. Higher doses of DAP produced a decline in the response rate and then complete cessation of responding. A dose-effect function was then obtained for the same DAP doses during 3-mo regimens involving single or multiple exposures to MW radiation. Under single exposure conditions, the subject first received the drug and then was exposed for 30 min to MW radiation at peak and average power densities of 1,000 mW/cm² and 1 mW/cm², respectively. The resulting whole-body dose rate was near 200 μW/g. In the multiple-exposure experiments, the subject was exposed to MW radiation under the same field conditions for 30 min/day, 4 days/wk, except on days when DAP was administered. Under both conditions of exposure, the dose-effect function for DAP was displaced such that the maximal behavior effect was obtained at doses lower than those without MW radiation.

6587 SOME PECULIARITIES OF AUDITORY SENSATIONS EVOKED BY PULSED MICROWAVE FIELDS. *(Eng)* Tyazhelov, V. V. (Inst. Biological Physics, Acad. Sciences, Pushchino, Moscow Region, 142292, USSR); Tigranian, R. E.; Khizhniak, E. O.; Akoev, I. G. *Radio Sci* 14(6S): 259-263; 1979 (12 refs).

Rectangularly pulsed 800-MHz microwaves (5-150 μsec pulse width; 50-20,000 pulses/sec) were coupled via a waveguide from a 500-W source to the parietal area of the head of normal human subjects to study the nature of microwave-evoked auditory sensations. Sine-wave audio frequency (AF) signals were presented alternately to or concurrently with microwave pulses (RF signal) under conditions such that the subject could adjust the amplitude, frequency, and phase of the AF signal. Timbre and loudness of the perceived RF and AF signals were matched during a succession of psychophysic measures. Both loudness and perceptual thresholds of the RF signal were biphasic functions of pulse width and of pulse repetition rate. When pulse widths increased toward 100 μsec, some subjects perceived a different sound, lower in pitch and referred externally to the head. By appropriate phasing of AF and RF signals after matching for pitch and timbre, loudness of the RF signal could be reduced below the threshold of perception. All of the qualitative sensory characteristics (pitch and timbre) evoked by microwave pulses of widths <50 μsec persisted when the subjects' heads were lowered into water. Loudness, however, diminished roughly in proportion to the depth of immersion. On complete immer-

sion, auditory sensations disappeared. For pulse durations longer than 50 μsec, even partial immersion resulted in loss of sensation. Although the thermoacoustic model for microwave-induced auditory sensations is correct at higher peak densities and shorter pulses of irradiation, it is inadequate for explaining a number of the peculiarities of auditory sensation observed in this study near threshold levels of sensation.

6588 DIAGNOSIS OF PULMONARY EDEMA BY A SURGICALLY NONINVASIVE MICROWAVE TECHNIQUE. *(Eng)* Iskander, M. F. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Shoff, D. J.; Bragg, D. G. *Radio Sci* 14(6S): 265-269; 1979 (8 refs).

A surgically noninvasive microwave technique for diagnosing pulmonary edema is described. High sensitivity of the method is related to the phase of the transmission coefficient, which is the most labile element in the scattering matrix. This sensitivity, although first predicted by theoretical analysis on a planar model, was verified experimentally with an agar-saline model of the thorax. From calculations, an optimal frequency between 740 MHz and 1.5 GHz was identified for a man-sized model. A new microwave applicator consisting of a 50-ohm surface-strip transmission line (coplanar waveguide) was developed for coupling 915 MHz energy into tissues with minimal external radiation. Other advantages of this strip-line concept included its low mass, small size, and flat configuration. The new applicator was used in six experiments with dogs. In all cases, pulmonary edema was induced either by rapid infusion of low- or high-molecular weight dextran or by infusion of freshly transfused blood; the process was reversed either by infusing Lasix (furosemide) or by bleeding the dog, respectively. Phase shifts were closely correlated with changes in pulmonary arterial pressure values, which are assumed to be sensitive to edema. In one experiment, a phase change of more than 150 degrees was observed after infusing 650 ml of blood into the femoral vein. Reversed changes of phase were observed when the process was reversed by bleeding the dog. Problems associated with this microwave diagnostic technique include holding the transmitting and receiving applicators in a fixed position relative to the thorax and the need to develop an adequate theoretical model. The planar model has proven to be inadequate for quantitative interpretation of the experimental observations.

6589 A COMPARISON OF PATTERNS OF STRAY RADIATION FROM THERAPEUTIC MICROWAVE APPLICATORS MEASURED NEAR TISSUE-SUBSTITUTE MODELS AND HUMAN SUBJECTS. *(Eng)* Lehmann, J. F. (Dept. Rehabilitation Medicine, Bioelectromagnetics Res. Lab. RJ-30, Univ. Washington Sch. Medicine, Seattle, WA 98195); Stonebridge, J. B.; Guy, A. W. *Radio Sci* 14(6S): 271-283; 1979 (23 refs).

Patterns of stray radiation from three different therapeutic microwave applicators were measured near tissue-substitute models and human subjects. The tissue-substitute models were a plane-layered block, a large cylinder, a thigh-model cylinder with one flat side, and a small cylinder. The following applicators were tested: a 11.4-cm corner reflector (C director) operating at 2,450 MHz, a 13-cm² direct-contact 915-MHz microwave applicator with radome and surface-cooling capability, and a 15.2-cm diameter circularly polarized 2,450-MHz Transco applicator with a surrounding choke assembly for suppressing stray radiation. Human volunteers were irradiated by the 915-MHz direct-contact applicator and by the 2,450-MHz Transco applicator. The human anatomic sites irradiated were chosen for their geometric similarity to the tissue-substitute models. When the direct-contact applicators were not in complete contact with the model or subject, levels of stray radiation >5 mW/cm² were measured at points 5 cm from the external surface of the applicator. The noncontacting C director had stray radiation levels >5 mW/cm² at 5 cm from the applicator in all directions. When the electric field was perpendicular to the long axis of the muscle or the model, higher levels of stray radiation were measured. Measurements of radiation levels during exposure of simple geometric models did not accurately predict the radiation levels measured near the corresponding anatomy of human subjects. The worst discrepancies existed when comparing the radiation levels near the lateral lumbar and upper back areas; the distances from the applicators to the 5 mW/cm² isopower-density levels were <5 cm when using the planar-tissue model, but were as high as 16.8 cm when using human subjects.

6590 DESTRUCTION OF SOLID TUMORS BY HEATING WITH RADIO-FREQUENCY ENERGY. *(Eng)* Dickson, J. A. (Cancer Res. Unit, Univ. Dept. Clinical Biochemistry, Royal Victoria Infirmary, Newcastle upon Tyne, England). *Radio Sci* 14(6S): 285-295; 1979 (28 refs).

Tumors of various types and sizes in the limbs of rats and rabbits were destroyed without damage to normal tissues by 13.56-MHz continuous wave diathermy heating to tumor temperatures of near 50 C for periods ranging from 15 to 60 min. A condenser-field technique was used, and direct-contact electrodes were applied at the site of the tumor. Temperature was continuously monitored via sensors at multiple sites within and outside of the tumor so that a lethal dosage of thermal energy could be delivered to the tumor and could be quantitated in terms of the product of temperature and time. The favorable ratio of deep-to-surface heating facilitated tumor destruction without damage to normal tissues. Initial work in-

dicates that this tumor-heating technique has the potential for the selective heating of limb tumors in man.

6591 EXPERIMENTAL AND NUMERICAL STUDIES OF THE ELEVATED TEMPERATURES INDUCED IN A HUMAN LEG BY MICROWAVE DIATHERMY WITH SURFACE COOLING. *(Eng)* Emery, A. F. (Dept. Medical Engineering, Univ. Washington, Seattle, WA 98195); Stonebridge, J. B.; Sekins, K. M.; Lehmann, J. F. *Radio Sci* 14(6S): 297-304; 1979 (10 refs).

A 915-MHz direct contact microwave diathermy process with an integrated system for surface cooling was modeled and was then applied for treatment of the anterior portion of the human thigh. This finite-element thermal model employs convective cooling conditions and microwave-energy deposition patterns obtained from experiments on phantom models. Numerical calculations were performed for a treatment regime that included 5 min of thigh precooling before microwave heating; the treatment schedule was designed to yield the desired therapeutic temperatures in deep musculature without creating unacceptably high temperatures in the more superficial tissues. Thigh temperatures were measured in human subjects undergoing the same diathermy process, with cooling being maintained throughout the treatment period. The measured temperatures were compared to the computed values to evaluate the validity of the finite-element model. This comparison indicated that this type of numerical simulation can be used to study the optimal relationships among precooling time intervals, air temperatures, flow rates, and microwave power. To improve this simulation capability, further study into the local thermophysiology of the subcutaneous tissue layer appears warranted as does some improvement in the measurement accuracies of this type of in vivo human experiment.

6592 THE RESPONSE OF PIG SKIN TO COMBINED X-IRRADIATION AND MICROWAVE HEATING. *(Eng)* Hand, J. W. (MRC Cyclotron Unit, Hammersmith Hosp., Ducane Rd., London W12 0HS, England); Field, S. B.; Hopewell, J. W.; Foster, J. L. *Radio Sci* 14(6S): 305-309; 1979 (11 refs).

To investigate the effect of heating induced by microwaves on skin response to ionizing radiation, areas on the flanks of female large white English pigs were given either single doses of x-rays alone (1,800-2,610 rads), or x-rays (1,000-1,750 rads) followed by microwave heating, or multiple doses (3 fractions over 6 days) of x-rays alone (2,700-3,900 rads) or x-rays (1,600-2,800 rads) followed by microwave heating. Heating to 42 C for 1.5 hr was produced with a microwave direct-contact applicator operating at 2.45 GHz. Early skin reactions were scored quantitatively by an arbitrary numerical system. For all treatments, microwave heating was shown to have little effect in enhancing the response of pig skin to ionizing radiation.

6593 TREATMENT OF EXPERIMENTAL WOUNDS IN RABBITS BY RADIO-FREQUENCY ELECTROMAGNETIC RADIATION. *(Eng)* Photiades, D. P. (Univ. Benin, Benin City, Nigeria); Osamo, N. O. *Radio Sci* 14(6S): 311-312; 1979 (5 refs).

To verify that accelerated cutaneous wound healing occurs after electromagnetic wave irradiation, 12 adult naive rabbits of a white inbred strain were exposed to pulsed 14.2-MHz radio frequency radiation. The animals were individually exposed to radiation in the near field (pulse duration, 200 μsec; pulse frequency, 120 pulses/sec) for 20 min/day on 10 consecutive days beginning 1.5 hr after the surgical induction of a sterile wound along the dorsum of the ear. Twelve sham-irradiated animals served as controls. Radiation-induced increments of ear temperature near the wound averaged 1.6 C. The criterion of wound healing was strength of the union at the incision site as judged by the absence of separation when the ear was bent longitudinally between the fingers. The median number of days to healing was 9 days for the controls compared with 6 days for the irradiated rabbits. A Chi-square statistical analysis of the data at the overall median of 8.5 days, revealed a statistically significant ($p<0.05$) enhancement in wound healing of about 30%. Experimental resolution of the effects of local heating and pulsing on the rate of wound healing are necessary to facilitate the clinical application of radio frequency electromagnetic energy.

6594 LOCALIZED EMBEDDING OF LABELLED MICROSPHERES BY MICROWAVE HEATING IN TISSUES OF HYPOTHERMIC DOGS. *(Eng)* Popovic, V. (Dept. Physiology, Emory Univ. Medical Sch., Atlanta, GA 30322); Popovic, P. *Radio Sci* 14(6S): 313-319; 1979 (34 refs).

The right hind leg of mongrel dogs was cooled by immersion to a temperature of 4-6 C while the gracilis muscle of the same leg was kept normothermic or slightly hyperthermic (37-39 C) by microwave heating with 2,450 MHz continuous waves to examine the effect of differential hypothermia on perfusion through the gracilis muscle. The circulation was measured by trapping of ^{99}Tc-labeled carbonized microspheres in the capillaries. The experiments demonstrated that circulation through the warmed muscle tissues was 5-12 times greater than that through the cold muscles of the same leg. When differential hypothermia was used to induce selective embedding of ^{90}Yttrium-loaded microspheres in the warm gracilis

muscle of the cooled leg, pronounced damage and even complete destruction of normothermic muscle tissue was observed, while no damage was seen in the other cold muscle tissues of the same leg. When the same amount of ^{90}Yttrium-loaded microspheres was administered during normothermic conditions, only slight damage or no damage was seen in the leg muscles. It is suggested that differential hypothermia might be useful for preferentially embedding either biologically important pharmaceuticals or medical radionuclides whenever superselective catheterization of tumors or other tissues is not possible.

6595 SPECIAL SECTION ON THE BLOOD-BRAIN BARRIER: INTRODUCTION BY THE EDITORS. *(Eng)* Justesen, D. R., editor (VA Medical Center, Kansas City, MO 64128). *Radio Sci* 14(6S): 321-322; 1979 (6 refs).

Studies on the effect of microwave irradiation on the blood-brain barrier are summarized. In one study, rats were subjected once to continuous wave (CW) or pulsed 1.3-GHz fields for 20 min at average power densities that ranged upward from 30 $\mu W/cm^2$. Modest but reliable increases of permeation of the blood-brain barrier by various intravascularly introduced tracers were reported. In another study, rats were exposed once to CW or pulsed 1.2-GHz fields for 30 min at average power densities that ranged upward from about 100 $\mu W/cm^2$. Sodium-fluorescein was administered as tracer. Highly reliable differences in the direction of greater fluorescence in irradiated brains were reported, especially for brains subjected to pulsed fields. However, a third study that attempted to repeat the procedures of the above two studies produced uniformly negative results. Uptake of sodium-fluorescein in brains of irradiated rats (as measured by a quantitative technique) also yielded negative results in spite of incident fields that ranged from 1 to 37.5 mW/cm^2. Only by heating rats to a high temperature by conventional means or by infusing them with urea, was acceptable evidence of increased blood-brain barrier permeability observed. A reanalysis of the data, however, via an analysis-of-variance technique, demonstrated that significant heating of the brain had occurred at modest power densities. It was also demonstrated that the quantitative measure of uptake of sodium-fluorescein was sensitive to microwaves within the range of field strengths employed. Whether this is a reflection of increased permeability of the blood-brain barrier or of altered cerebral circulation will be debated.

6596 REVERSIBILITY OF MICROWAVE-INDUCED BLOOD-BRAIN-BARRIER PERMEABILITY. *(Eng)* Albert, E. N. (Dept. Anatomy, George Washington Univ. Medical Center, 2300 I St., NW, Washington, DC 20037). *Radio Sci* 14(6S): 323-327; 1979 (15 refs).

Reversibility of microwave-induced increases in brain-capillary permeability was investigated in 18 Wistar rats and 34 Chinese hamsters. The animals were anesthetized and their heads were irradiated in the near field with 2,800-MHz continuous wave microwaves at a power density of 10 mW/cm^2 for 2 hr. Eight rats and 12 hamsters were anesthetized and sham-irradiated and served as controls. Horseradish peroxidase protein was injected (10 mg in 0.2 cm^3 saline) as a tracer and its transport across capillaries in all regions of the brain was observed. Alterations in the permeability of the blood-brain barrier after irradiation were evidenced by the leakage of horseradish peroxidase from blood vessels into surrounding brain parenchyma. However, gross and electron microscopic observations indicated that re-establishment of the relative impermeability of the blood-brain barrier was significant but partial at 1 hr and was complete at 2 hr after the cessation of irradiation. Preliminary studies with two hamsters demonstrated that the iris capillaries became more permeable to the circulating peroxidase after microwave irradiation, indicating that the blood-ocular barrier was similarly affected.

6597 EFFECTS OF MICROWAVE-INDUCED HYPERTHERMIA ON THE BLOOD-BRAIN BARRIER OF THE RAT. *(Eng)* Sutton, C. H. (Dept. Neurological Surgery, Univ. Miami Sch. Medicine, Box 520875, Miami, FL 33152); Carroll, F. B. *Radio Sci* 14(6S): 329-334; 1979 (27 refs).

The effects of 2,450-MHz continuous wave microwave-induced hyperthermia on the blood-brain barrier of male Sprague-Dawley rats (250 g) were investigated by heating the animal's head selectively in the near field while shielding the remainder of the body. The initial studies used a model 200 Burdick medical microwave diathermy generator; later studies utilized a model 225 Burdick generator. An enzymatic tracer protein, horseradish peroxidase, was administered intravenously (0.18 g/kg) to each rat 30 min before euthanasia. Biochemical quantitation of extravasated peroxidase in homogenized brains of animals was the index of barrier permeation. In initially normothermic (37 C body core temperature) rats, blood-brain barrier integrity was diminished after heating of brains for 10 min at 45 C, after 15 min at 42 C, and after 60 min at 40 C. In rats precooled to a body core temperature of 30 C, blood-brain barrier integrity was diminished after heating of brains for 15 min at 45 C, after 30 min at 42 C, and after 180 min at 40 C. In addition to protecting the integrity of the blood-brain barrier, body-core hypothermia at 30 C also lengthened survival time significantly. For example, it was possible to maintain the brains of hypothermic animals at 45 C for as long as 90 min without mortality, while most normothermic rats expired after a 15-min treatment. It is concluded that intense microwave-induced hyperthermia can increase the permeability of the blood-brain barrier and that the tolerance of the blood-brain barrier to microwave

irradiation is dose-related. For therapeutic heating of the brain by microwave energy, it is suggested that the temperature of normal brain tissue should not exceed 40 C and that periods of hyperthermia should be limited to ≤30 min because of the danger of brain edema. However, systemic hypothermia concurrent with irradiation permits higher temperatures and longer durations of exposure without indications of morbidity.

6598 PROBLEMS OF QUANTIFYING EFFECTS OF MICROWAVE IRRADIATION ON THE BLOOD-BRAIN BARRIER. *(Eng)* Blasberg, R. G. (Natl. Cancer Inst., NIH, Building 37, Room 5A13, Bethesda, MD 20014). *Radio Sci* 14(6S): 335-344; 1979 (47 refs).

Techniques used to quantify microwave-induced alterations in the blood-brain barrier (BBB) are reviewed in relation to the uncertainties of microwave effects on the BBB. It has not been clearly determined whether microwave irradiation in the absence of gross or focal heating has any effect on normal function of the BBB. This ambiguity may be due to the unknown magnitudes of microwave-induced effects and to uncertainty with the sensitivity and quantitative accuracy of the measurements. Although histologic methods (e.g., morphologic observations and tracer studies) can detect both diffuse and focal alterations of BBB function, most of the methods are nonquantitative. Seven different physiologic methods that involve four different tracer input modalities are discussed. The physiologic methods, as classified by tracer input modality, are as follows: intra-arterial bolus (2 methods), intravenous bolus (1), intravascular infusion (1), ventriculocisternal perfusion (1), and tissue washout (2). The approximate lower limits of permeability that can be measured by these methods, where permeability is expressed in terms of a transfer constant with the dimensions of min^{-1}, are: 3×10^{-2}, and 3×10^{-2}, 1×10^{-5}, 1×10^{-4}, 1×10^{-3}, and 1×10^{-1} and 1×10^{-1}, respectively. Advantages and disadvantages of these methods are discussed along with their applicability to studying the effects of microwaves on normal BBB function. Although the washout method for studying the effects of microwaves on BBB function is limited by the fact that only a narrow range of solutes (those that are moderately permeable) can be studied, this method has several advantages if an external monitoring technique is used. One advantage is that the effect of microwaves on both permeability and blood flow can be measured simultaneously in the same animal; these measurements can be made sequentially during and following microwave exposure, and the technique is applicable to human study. Consideration of the experimental design and its associated quantitative limits are essential when investigating the effects of microwave irradiation on the BBB.

6599 A QUANTITATIVE METHOD FOR MEASURING ALTERED CEREBROVASCULAR PERMEABILITY. *(Eng)* Rapoport, S. I. (Lab. Neurosciences, Natl. Inst. Aging, Gerontology Res. Center, Baltimore City Hosp., Baltimore, MD 21224); Ohno, K.; Fredericks, W. R.; Pettigrew, K. D. *Radio Sci* 14(6S): 345-348; 1979 (15 refs).

A method for measuring regional cerebrovascular permeability to ^{14}C-sucrose is described that should be useful for studying the effects of microwaves on the cerebral vasculature. Cerebrovascular permeability to ^{14}C-sucrose was measured independently of cerebral blood flow in the rat following unilateral osmotic opening of the blood-brain barrier by hypertonic arabinose solution. An increase in regional permeability to ^{14}C-sucrose was correlated with the extent of brain staining by intravascular Evans blue-albumin, a visual barrier tracer. To obtain the product of capillary permeability and surface area, ^{14}C-sucrose was injected intravenously, the arterial plasma concentration curve was determined and integrated over a 10-min period, and brain parenchymal concentration was calculated after subtracting vascular radioactivity from net tissue radioactivity. Conditions were chosen so that a simple diffusion equation could be applied to exchange between plasma and brain compartments in the absence of back flux from brain. This method for measuring altered cerebrovascular permeability is 100 times more sensitive than the Brain Uptake Index technique.

6600 STUDIES OF THE BLOOD-BRAIN BARRIER: PRELIMINARY FINDINGS AND DISCUSSION. *(Eng)* Frey, A. H. (Randomline, Inc., County Line and Mann Rd., Huntingdon Valley, PA 19006). *Radio Sci* 14(6S): 349-350; 1979 (no refs).

Studies on the effects of microwaves on the blood-vitreous humor, blood-brain, and placental barriers are reported. In the first study 36 Sprague-Dawley rats were injected with a sodium-fluorescein-in-saline solution into the femoral vein and were exposed in an anechoic chamber at an average power density of 0.1 mW/cm² to 30 min of 1.2-GHz pulsed radiation (pulse modulated at 7.5 pulses/sec; with a pulse width of 10 μsec) to study the possibility of breaking down the blood-vitreous humor barrier. The exposed animals showed a significantly increased ($p<0.01$) fluorescence in the vitreous humor compared to sham-exposed control animals. In two studies on the placental barrier of Spraque-Dawley rats, anesthetized pregnant females (gestational age, 11-19 days), which had first been injected with sodium-fluorescein solution, were exposed in an anechoic chamber at an average power density of 0.1 mW/cm² to 1.2-GHz pulsed radiation (pulse modulated at 7.5 pulses/sec; pulse width of 10 μsec). No significant differences were found between 77 exposed and 79

sham-exposed fetuses in terms of the degree of fluorescence of fetal materials. In a similar experiment where the gestational age was 14-18 days and where the power density was increased to 4 mW/cm² for a 1.2-GHz pulsed carrier signal (pulse modulated at 50 pulses/sec; pulse width of 10 μsec), no significant difference in fetal fluorescence was found between sham-exposed and microwave-exposed fetuses. Experimentation has also been initiated in which autoradiographic techniques are used to determine if low-intensity microwave energy can be used to facilitate the passage of cancer chemotherapeutic drugs into the brain. Although the details of this experiment are not discussed, it is considered to be a promising line of investigation.

6601 DISCUSSION: THE BLOOD-BRAIN BARRIER, CEREBRAL CIRCULATION, AND MATHEMATICAL MODELING. *(Eng)* Justesen, D. R. (VA Medical Center, Kansas City, MO 64128). *Radio Sci* 14(6S): 351; 1979 (no refs).

A brief discussion of the effects of microwave fields on the blood-brain barrier and cerebral circulation is presented. There is increasing doubt that microwave fields that result in trivial elevations of brain temperature can affect the tight junctions of the blood-brain barrier. However, some findings indicate that such microwave fields may result in neurocirculatory responses. Also discussed are problems associated with densitometry and the role of mathematical modeling in biology. Some basic biologic knowledge and techniques must be discovered before the effects of microwaves on the blood-brain barrier permeability can be fully understood.

6602 QUANTITATION OF EFFECTS OF REPEATED MICROWAVE RADIATION ON MUSCLE-CELL OSMOTIC STATE AND MEMBRANE PERMSELECTIVITY. *(Eng)* Portela, A. (Instituto de Investigaciones Biofisicas, Consejo Nacional de Investigaciones Cientificas y Tecnicas, Callao 930, Buenos Aires 1023, Republica Argentina); Guardado, M. I.; de Xammar Oro, J. R.; Brennan, M.; Trainotti, V.; Stewart, P. A.; Perez, R. J.; Rodriguez, C.; Gimeno, A.; Rozzell, T. C. *Radio Sci* 14(6S): 127-139; 1979 (23 refs).

Frogs *(Rana pipiens)* were exposed to 2.88-GHz pulsed microwave radiation (900 pulses/sec, 0.67 μsec pulse duration) at an average power density of 10 mW/cm² (average whole-body specific absorption rate, 1.5 mW/g/mW/cm²) for 6 min/day during successive periods of 20, 40, 60, 80, and 100 days to determine the effect of such exposures on muscle cell osmotic state and membrane permselectivity. Single-fiber preparations of tibialis anticus muscle were analyzed for osmotic responses. The following quantities were determined: osmotically effective cell-water fraction (Weff); cell-membrane water permeability (Pw); Staverman's reflection coefficient for mannitol, sucrose, glycerol, urea, acetamide, ethylene glycol, and formamide; and equivalent pore radius of the membrane (Rmp). No changes were detected in any of these endpoints as a consequence of repeated exposure to pulsed microwave radiation. Mean values found were: Weff = 0.50, Pw = 0.40 cm⁴/osmolar/sec, and Rmp = 4 Angstroms.

6603 MICROWAVES--NO CAUSE FOR HYSTERIA. *(Eng)* Hamilton, M. (No affiliation given). *Occup Saf Health* 9(12): 14, 15, 18, 19, 38; 1979 (no refs).

General information about microwaves is presented in response to public concern in the United Kingdom over possible exposure from microwave ovens. Topics reviewed include: characteristics of microwaves, exposure safety standards in the United Kingdom, disagreement between the West and the Eastern Bloc nations concerning the biologic effects of microwave exposure and safe limits for exposure, the possibility of revision of exposure standards in the West, and information concerning microwave oven leakage limits. The safe limit allowed for microwave oven leakage is 5 mW/cm² at 5 cm from the oven door. The worst leakages found in microwave oven surveys have been only 10 mW/cm², which is not enough to feel warmth even on direct contact with the door edge. Microwave oven manufacturers claim that there is no known case among 15 million oven users throughout the world, of anyone being injured by microwaves from an oven.

6604 DOCUMENTING RADIATION EFFECTS. *(Eng)* Anonymous (No affiliation given). *Occup Health Saf* 48(7): 54-57; 1979 (33 refs).

Radiation work at NIOSH, incorporating input from four major research programs (biologic effects studies, protective devices, control measures, and hazard evaluations), is reviewed. Studies of microwave/radio frequency (RF) radiation conducted by the Physical Agents Effects Branch (PAEB) of NIOSH have included the fabrication of an exposure chamber, the development of near-field electric and magnetic field meters, field surveys, and RF bioeffect studies. Over 1,400 measurements on various RF sources typically found in the workplace have been completed, and at least 75% of the sources surveyed exceeded the current personnel radiation protection guidelines set by the American National Standards Institute. NIOSH has recently initiated a program to

investigate teratogenic effects. These studies are being conducted on rats at frequencies under 40 MHz where most industrial RF sources operate. Because of the difficulties in making meaningful biologic measurements in the area from 10-500 MHz, it has been necessary for PAEB to acquire information on special techniques such as phantom modeling, six-port analysis, and dielectric measurements. Since absorbed dose values rather than change in temperature may be of more importance in RF biologic measurements, PAEB has worked with NBS on the development of new measurement systems. Such a system is undergoing testing at this time.

6605 MICROWAVE POWER APPLICATIONS IN THE WORLD: PRESENT AND FUTURE. *(Eng)* Schiffmann, R. F. (R. F. Schiffmann and Associates, 149 West 88th St., New York, NY 10024). *J Microwave Power* 14(3): 197-200; 1979 (no refs).

The development of microwave power applications is reviewed, with particular emphasis on present and possible future applications. In the food industry alone, there are over 100 microwave installations; these are used for meat tempering, donut proofing and frying, meat cooking, pasta drying, fish thawing, poultry cooking, and vacuum drying. Non-food applications include industrial systems for rubber vulcanization, rubber preheating, heating of foundry cores, and the drying of vitamins. In the area of biomedical applications, work on the selective microwave heating of tumors and of whole or partial body hyperthermia holds promise for the successful treatment of cancer, particularly when microwaves are used in conjunction with other therapies such as radiation and chemotherapy. The potential for the treatment of brain tumors without surgery is particularly important because of the special problems associated with brain surgery. Other biomedical applications include the use of microwaves for the rapid thawing of blood or frozen donor organs and for diagnostic purposes.

6606 STANDARDS FOR MICROWAVE RADIATION. *(Eng)* Blackwell, R. P. (Natl. Radiological Protection Board Lab., Harwell, Oxford, England). *Nature* 282(5737): 360; 1979 (5 refs).

Differences between the Western and Eastern standards for maximum permissible exposure to radio frequency and microwave radiation are discussed. The Western standard of 10 mW/cm^2 is derived from thermal considerations, whereas the Eastern standard of 10 μW/cm^2 is based on the assumption that any detectable biologic change constitutes a hazard. A large proportion of reports from Eastern Europe concern behavioral, electrophysiologic, and strongly subjective changes of a generalized nature that are difficult to quantify. Fatigue, memory loss, and loss of concentration have been reported. Many of the reports of experiments performed by Soviet workers have been criticized, particularly in terms of dosimetry and experimental detail. Although the body of evidence produced in the West is not in accord with many of the Eastern findings, one study indicated that changes in the calcium ion efflux of chick and cat brain tissue in vitro can be modified by exposure to amplitude-modulated very high frequency (VHF) fields of 1 mW/cm^2. Unmodulated fields do not produce an effect; however, electrostatic fields alternating at the modulation frequency (6-30 Hz) do. One major development that any revised standard must take into account is the resonance effects that occur in man in the low VHF region.

6607 SPURIOUS RADIATION FROM MICROWAVE OVENS. *(Eng)* Anderson, B. (Nuffield Radio Astronomy Lab., Univ. Manchester, Jodrell Bank, Macclesfield, Cheshire, England); Pritchard, R.; Rowson, B. *Nature* 282(5739): 594-596; 1979 (6 refs).

Measurements for spurious radiation outside the licensed band of 2.450 ± 50 MHz were made on three microwave ovens in the United Kingdom. Two of the ovens were new domestic models currently on sale, and the third was a larger commercial model that had been in service for 10 yr and was coated with deposits of grease and grime. Although the instantaneous frequency of the ovens was found to be within the assigned band of 2.450 ± 50 MHz, modulation sidebands were detected that produced out-of-band emissions. It is also possible that some of the spurious emissions were caused by instabilities in the electron distribution inside the magnetron, leading to the generation of unwanted frequencies. The primary source of radiation leakage from these ovens was from the seals around the door, which failed to confine the microwave radiation to the inside of the oven. These seals are noncontacting and seem to consist of a resonant, quarter-wavelength choke, nominally tuned to 2.450 MHz, followed by microwave absorbing material. The seals are sufficiently effective in the assigned band of 2.450 MHz to satisfy the safety regulations in the United Kingdom, but they fail to give adequate out-of-band suppression to prevent possible interference with other services authorized to operate within the 1- to 6-GHz frequency band.

6608 MICROWAVE RADIATION: AN EPIDEMIOLOGIC ASSESSMENT. *(Eng)* Albrecht, R. M. (BRH, FDA, Rockville, MD 20857); Landau, E. *Rev Environ Health* 3(1): 43-58; 1979 (31 refs).

Epidemiologic studies of exposure to radio frequency and microwave radiation are reviewed, with par-

ticular emphasis on low-level exposure. In addition, definitions, sources, uses, and reported effects of microwaves are briefly presented. Publications of Soviet and Eastern European studies indicate that microwave and radio frequency fields can functionally, and even morphologically at times, alter the organism exposed at field flux or power densities below those that cause measurable heating. Reversible changes in behavior, function, and microstructures are frequently reported at power densities well below the Western world's safe exposure level of 10 mW/cm². The prevailing Western view, particularly in the United States, is that the effects of microwave and radio frequency fields are attributable only to the heating mechanism of fields that are generally associated with power densities greater than 10 mW/cm². In the U.S., the only generally accepted reported effects in man are minor lens defects and skin damage. Investigators of nonthermal microwave radiation effects report that prolonged industrial exposure to intensities <10 mW/cm² may cause a variety of adverse health effects, including headache, fatigue, irritability, dizziness, loss of appetite, sleepiness, sweating, difficulties in concentration, poor memory, depression, emotional instability, dermographism, thyroid gland enlargement, and tremor of the extended fingers. These are regarded as typical microwave-induced functional disturbances of the central nervous system and are called the *neurasthenic* syndrome. Another syndrome consists of labile pulse and blood pressure with electrocardiogram changes. A third is the diencephalic syndrome that includes insomnia and hallucinations. It is concluded that additional epidemiologic studies of radio frequency and microwave bioeffects are needed, including studies of primarily neural and behavioral disorders, as are studies of sizable U.S. populations with relatively high microwave exposures for observation of long-term effects.

6609 THE RADIOWAVE SYNDROME. *(Eng)* Gold, M. (No affiliation given). *Sci 80* 1(1): 78, 80-84; 1979 (no refs).

Experiments involving low-level exposures to radio frequency and microwave radiation are reviewed in relation to current occupational exposure guidelines and environmental levels of nonionizing electromagnetic radiation in the United States. In addition, several cases of electronic smog emanating from various electronic devices are described. Results from a pivotal experiment conducted in the U.S. (a re-creation of an earlier Russian study) showed that a power density 20 times lower than the current U.S. occupational guideline of 10,000 μW/cm² altered the behavior and blood chemistry of laboratory rats. In another experiment, cats exposed to radio power densities as low as 100 μW/cm² showed significant changes in the distribution of calcium ions in the central nervous system. It appears that basic physiologic changes similar to those observed in recent animal experiments may produce the human symptoms reported by the Russians and East Europeans, although this has not been conclusively demonstrated. EPA measurements of environmental levels of nonionizing electromagnetic radiation have revealed power densities of several thousand μW/cm² on the ground below broadcast towers and power densities of 50 and 100 μW/cm² in tall buildings near broadcast transmitters. Measurements as high as 10,000 μW/cm² have been recorded 6 inches from electronic surgical knives and within 5 inches of walkie-talkies. Measurements by NIOSH of occupational exposure levels near 82 plastic sealers disclosed that 60% exceeded the recommended safety limit and that some of the operators were exposed to fields 26 times the limit.

6610 HEALTH ASPECTS OF RADIO AND MICROWAVE RADIATION. *(Eng)* Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ., Detroit, MI 48202). *J Environ Pathol Toxicol* 2(16): 1413-1432; 1979 (59 refs).

Animal experiments on low-level effects of radio frequency and microwave radiation (1 MHz-300 GHz) are reviewed. In addition, some measurements of environmental exposure in the United States are presented and the adequacy of existing exposure standards are discussed. Cytologic, neural, and behavioral effects have been reported in mammals exposed to low levels (<10 mW/cm²) of radio frequency and microwave radiation. These changes are associated with little or no measurable temperature rise and have generally been reported to be reversible. Measurements of environmental radio frequency and microwave radiation in 10 large U.S. cities and analyses of population distribution indicate that 99% of the urban population is exposed to <0.001 mW/cm². The remaining 1% is exposed to much higher densities in the immediate vicinity of transmitting antennas. Allowing a 10-fold difference in the average specific absorption rates between animals and humans, it is conceivable that changes similar to those reported in animals might be induced in humans near the 10-mW/cm² limit. Considering individual variations of health status and susceptibility and a safety factor of 10, a maximum possible limit of 1 mW/cm² for indefinite continuous wave exposure seems realistic from the viewpoint of protecting the general population.

6611 HIGH VOLTAGE LINES: HAZARD AT A DISTANCE. *(Eng)* Marino, A. A. (VA Hosp., Syracuse, NY); Becker, R. O. *Environment* 20(9): 6-15, 40; 1978 (34 refs).

Research on the biologic effects of extremely low frequency (ELF) electromagnetic fields is discussed in relation to the fields generated by high voltage lines operating at a frequency of 60 Hz. Presently there are more than 100,000 miles of overhead high

voltage lines in the United States carrying up to 765,000 V. A review of animal and human studies performed over periods ranging from 10 min to 600 days at frequencies ranging from 0.2 to 640 Hz with applied fields of 0.0007 to 6,000 V/cm, 1 to 3 G, or 1 $\mu A/cm^2$ indicates that the following effects as a result of ELF exposure: behavioral changes, cell and animal death, growth disorders, biochemical changes, hematologic changes, neurologic effects, cardiovascular changes, and general changes in physiology. For human subjects in particular, changes in reaction time, neurologic effects, and cardiovascular disorders have been observed as a result of ELF exposure. Since the acutal situation that exists near overhead high voltage lines, i.e., simultaneous application of both the electric and magnetic fields, has not been studied, there is a possibility of a synergistic interaction between the fields in subjects exposed to these lines and also between the energy flux, the fields taken together, and other agents in the environment.

6612 SELECTIVE TUMOR HEATING AND GROWTH RETARDATION BY SHORT-WAVE RADIOFREQUENCY. *(Eng)* Auda, S. P. (Dept. Surgery, Univ. Maryland, Baltimore, MD); Hall, G.; Elias, J.; Elias, E. G.; Vuthiganon, C. *Surg Forum* 30: 154-156; 1979 (5 refs).

Heating patterns, tumor growth, and survival of 40 isologous Fischer 344 rats bearing subcutaneously inoculated methylcholanthrene-induced sarcoma were compared at three different frequencies of shortwave radio frequency heating. When the tumors reached 0.9-1.6 cm^1, the rats were divided into five groups. A control group (8 rats) was sham heated. Three other groups (8 rats each) were treated with external high frequency dielectric heating with one of three different frequencies: 3.00, 13.56, or 27.22 MHz. All of these rats were treated once for 1 hr at a constant power density of 0.35 W/cm^2. A fifth group (8 rats) was treated with 27.22 MHz but the power was increased to 0.6 W/cm^2. Selective increases in tumor tissue temperature were observed in rats treated at 3.00 and 13.56 MHz. Tumor selectivity and overall temperature were more pronounced at the 3.00 MHz frequency. When 27.22 MHz was used at low power (0.35 W/cm^2), tumor temperature selectivity was not seen and tissue heating was minimal. To reach temperatures equivalent to those of the lower frequencies (43-44 C), the absorbed power had to be increased to 0.65 W/cm^2; at this power level, tumor selectivity was not seen. No heating was detected in the sham-heated group. The reduction of tumor growth in rats treated with 3.00 MHz was statistically significant when compared to the other groups. Total tumor regression for >30 days occurred in three of eight rats treated with 3.00 MHz, and their overall survival was markedly prolonged ($p<0.01$). One rat was cured for more than 3 mo.

6613 CANCER TREATMENT BY HYPERTHERMIA: INCLUDING PHANTOM STUDIES ON LOCALIZED HYPERTHERMIA PRODUCTION AND MEASUREMENT. *(Fre)* Pluygers, E. (Service d'Oncologie, Hopital de Jolimont, 7161 Haine-Saint-Paul, Belgium). *J Belge Radiol* 62(2): 155-171; 1979 (51 refs).

The general biologic and therapeutic effects of hyperthermia induced by different methods (e.g., hot fluid baths, perfusion of warm fluids, injection of bacterial toxins, short-wave diathermy, microwaves, radio frequency, and ultrasound) are reviewed with special regard to cancer therapy. Beyond a certain limit (41.5-42 C) the survival curve of isolated cells or cell cultures is similar to that of cells exposed to ionizing radiation. Hypoxic cells and cells in S-phase are most sensitive to hyperthermia. Complete and long-term remission of tumors, e.g., sarcoma S 180 and mammary adenocarcinoma, was observed in some experimental animals (SWR and C3H mice). Hyperthermia enhanced the effects of ionizing radiation and cytostatic drugs on tumors. Short-wave and microwave hyperthermia is used most commonly in oncologic therapy. Satisfactory regional hyperthermia can be obtained at a frequency of 27 MHz, but 433 MHz and 2.45 GHz are currently preferred. Implantable semirigid microwave generators operating at frequencies of 500 kHz to 15 MHz have been developed recently. The first results with local and regional hyperthermia, whether associated with radiotherapy or chemotherapy, were encouraging. The 2-yr survival rates achieved in 156 patients with cancer of the ear-nose-throat region was 29% in a group subjected to telecobalt therapy only, 36.5% in another group subjected to radiotherapy under hyperbaric oxygen therapy, and 75.5% in a third group subjected to telecobalt therapy and microwave hyperthermia.

6614 LOCAL MICROWAVE HYPERTHERMIA AS A TREATMENT OF CANCER. *(Eng)* Douple, E. B. (Dartmouth Medical Sch., Dartmouth Coll., Hanover, NH 03755); Strohbehn, J. W.; Walsh, J. E.; deSieyes, D. C. *In: Seventh Annual New England Bioengineering Conference held March 22-23, 1979 in Troy, NY.* pp. 248-251; 1979 (4 refs).

An invasive microwave system for producing local hyperthermia in tumors using a small microwave antenna similar to a hypodermic needle is described. The system employs a 1-GHz (3 W) oscillator, a crystal detector, attenuators, an oscilloscope, a dual-directional coupler, and a double-stub tuner to match the antenna and maximize the radiated power. Thermal distributions of between 42 and 46 C were produced by this system in 1-cm diameter mammary adenocarcinomas (MTG-B) implanted in thighs of C3H mice; a single, 50-min treatment inhibited tumor growth for a short period of time following treatment.

Tests on the therapeutic efficacy of this system with single or multiple 1-hr treatments (46 C near the antenna) showed that the heat treatment alone inhibited tumor growth and that the effect of both radiation therapy and chemotherapy was significantly enhanced when these treatments were followed by 1-GHz hyperthermia.

6615 FOUR YEARS OF MICROWAVES IN CANCER THERAPY. *(Eng)* Holt, J. (Radiotherapy Center, 24 Salvado Rd., Wembley 6014, Perth, Western Australia); Nelson, A. *J Belge Radiol* 62(5): 467-476; 1979 (13 refs).

The results of treating 1,300 patients (from 1974 to 1978) with active progressive cancer unresponsive to conventional treatment modalities by very high frequency (VHF) hyperthermia (434 MHz) for periods ranging from 15 to 60 min are reported. In a first phase of the study, 600 patients were treated by VHF alone, VHF followed by x-ray therapy, or VHF plus cytotoxic drugs. Over 90% of these 600 patients experienced subjective improvement, and about 70% showed objective improvement. In a second phase of the study, 700 patients were treated for cancer at the following sites: head and neck, breast and axilla, bone metastases, liver metastases, brain, lung, abdomen, rectum, bladder, sarcomata, and lymphomata. VHF was found to be a nontoxic form of therapy that is effective as a radiosensitizer for all types of cancer investigated. For example, the results for treating head and neck cancer by VHF and x-rays were three times better than those for x-ray therapy alone. VHF also enhanced the effectiveness of certain cytotoxic drugs and resulted in a synergism between cytotoxic agents and x-ray therapy.

6616 MICROWAVE APPARATUS FOR THE TREATMENT OF CANCER. *(Eng)* Sterzer, F. (Microwave Technology Center, RCA Lab., Princeton, NJ); Paglione, R.; Nowogrodzki, M.; Beck, E.; Mendecki, J.; Friedenthal, E.; Botstein, C. *Microwave J* 23(1): 39-42, 44; 1980 (3 refs).

Apparatus that use 915-MHz or 2,450-MHz microwave radiation for the controlled local heating of cutaneous and subcutaneous tumors as well as tumors located within or in the vicinity of natural body cavities are described. There are three basic types of microwave applicators that are used for localized hyperthermia treatment: waveguide types, conformal "bean-bag" types using printed circuit antennas, and coaxial types. Several of applicators may be used at one time to treat deep-seated or wide-spread tumors, e.g., primary breast tumors that are treated by applying two bean bag applicators to the breast so that the tumors are heated simultaneously from opposite directions. In a typical localized hyperthermia treatment, the temperature of the tumor mass is raised to approximately 42.5-43.5 C for 30-60 min at a time (normal body temperature is approximately 37 C). A temperature sensing and controlling device, a copper-constant in a thermocouple, is used to maintain a constant temperature in the tumors during hyperthermic treatment. The power densities required to accomplish this heating depend on the type and size of the tumor, its location, the blood circulation in the tumor and surrounding healthy tissues, and various other factors. Typical experimental values for power density are 1-2 W/cm^2. In one animal study involving 72 C3H mice implanted with mammary adenocarcinoma, all of 54 mice receiving four hyperthermia treatments localized to the tumor site (43 C, 45 min, every other day) achieved complete eradication of tumors; there was no evidence of tumor recurrence over a 4-mo observation period. In contrast, all 18 tumor-bearing controls died within 4 wk of inoculation. Types of human cancers that have been treated by hyperthermia include basal cell carcinomas, malignant melanomas, primary and metastatic breast cancers, prostate cancers, and liposarcomas. Results obtained to date are encouraging, indicating that hyperthermia is likely to become an important tool in cancer therapy.

6617 SYSTEM TO DETECT AND TREAT CANCER, USING MICROWAVES FOR BOTH TASKS. *(Eng)* Brinton, J. B. (No affiliation given). *Electronics* 52(26): 42; 1979 (3 refs).

An experimental microwave system for both detecting and treating tumors is described. The dual-mode system from Microwave Associates, Incorporated, Burlington, Massachusetts combines a radiometer for temperature measurement and a bipolar transistor oscillator for tissue heating or hyperthermia. The radiometer has been tested successfully on breast cancer patients, and the oscillator will soon be tested on animals. The radiometer operates at a frequency of 4.7 GHz, and the oscillator operates at a frequency of 1.6 GHz. Both subunits' antennas are joined in a single assembly. Microwave detection of tumors is possible because tumors are slightly hotter than the surrounding healthy tissue and emit greater energy. Hyperthermia, at a variety of radio frequencies, is showing promise as a well-controlled, nonsurgical technique for heating tumors to temperatures that destroy them while leaving healthy tissue unaffected.

6618 A MICROWAVE HYPERTHERMIA TREATMENT AND THERMOMETRY SYSTEM. *(Eng)* Kopecky, W. J. (Physics Section, Div. Radiation Oncology, Edward Mallinckrodt Inst. Radiology, Washington Univ. Sch. Medicine, St. Louis, MO 63110); Perez, C. A. *Int J Radiat Oncol Biol Phys* 5(11/12): 2113-2115; 1979 (7 refs).

A microwave hyperthermia and thermometry system for heating tumors in a very specific temperature

range is described. The microwave generator, with both variable power output and frequency (400-1,000 MHz) capabilities, is fed into an isolator that is used to permit full forward power to pass but absorbs all but a fraction of the reflected power. The generator has a built-in circuit that will place itself in a stand-by mode if the reflected power is greater than 10 W. The output of the isolator is then fed into a double stub tuner that is used to control mismatches between the applicator and the patient surface. The thermometry system consists of a dual channel strip chart recorder and thermistor probes, each feeding into an analog readout unit. Tumor core and tumor surface probes occupy the two channels of the strip chart recorder. A normal tissue surface probe that records manually by reading the third analog readout unit is also used. Since this system is being used in clinical protocols where hyperthermia is used after ionizing radiation, the thermistor probes are inserted after the ionizing radiation treatment and are oriented perpendicular to the microwave electric field to avoid induction of localized probe heating. Also, these probes are sufficiently shielded so that they are not affected by stray radio frequency radiation that may produce erroneous temperature readings. This equipment was used to treat 42 patients during the 1978 calendar year, and was found to be versatile and adaptable to existing clinical hyperthermia protocols.

6619 TEMPERATURE DISTRIBUTION IN LOCALIZED CURRENT FIELD HYPERTHERMIA–A THEORETICAL MODEL. *(Eng)* Strang, R. (No affiliation given). *In: Cancer Therapy by Hyperthermia and Radiation.* Proceedings of the 2nd International Symposium. (Essen, W. Germany) 344 pp.: 109-111; 1978 (2 refs).

A two-dimensional computer model was developed to predict the temperature at discrete points within an area of tissue that is subjected to localized current field (LCF) hyperthermia. The model assumes that the body can be represented by three tissue layers (fat/muscle/fat). The electrode arrangement was taken as two parallel plates, with the boundaries between the tissues parallel to the electrodes. The current density between the two plates was assumed to be uniform over the whole length of the plate, i.e., edge effects were ignored. In calculating the temperature distribution within the tissue layers, the following features were included in the model: thermal conduction, an LCF heating term, removal of heat by blood flow, and surface cooling. The results of the model indicate that the conduction of heat out of the heated area greatly modifies the temperature distribution. This implies that either the electrode plates have to be considerably larger than the volume of tissue being heated or that an electrode arrangement that gives preferential heating to the edges of the volume must be designed. Results from studies on the removal of heat by blood flow indicate the importance of this factor and the importance of the position of the equilibration point. Although the results from the model apply only to the simple case of two parallel plate electrodes, the model can easily be modified to cope with more elaborate electrode arrangements and other heating modalities.

6620 MICROWAVE THERAPY: STRAY RADIATION, SAFETY AND EFFECTIVENESS. *(Eng)* Lehmann, J. F. (Dept. Rehabilitation Medicine, RJ-30, Sch. Medicine, Univ. Washington, Seattle, WA 98195); Stonebridge, J. B.; Wallace, J. E.; Warren, C. G.; Guy, A. W. *Arch Phys Med Rehabil* 60(12): 578-584; 1979 (29 refs).

Stray radiation levels were determined for four therapeutic microwave diathermy applicators using four phantom tissue models and four human subjects. The phantom tissue models used were two cylindrical models of fat, muscle, and bone (17.8 and 8.8 cm in diameter); a thigh model of fat, muscle, and bone; and a planar model of fat and muscle. The applicators were a 915-MHz linearly polarized direct-contact type, a 2,450-MHz circularly polarized direct-contact (Transco) applicator, and two 2,450-MHz dipole corner-reflector applicators (C- and E-directors). The maximum distance of stray radiation was measured from the applicator/model or applicator/tissue interface to the positions corresponding to measured power density levels of 5 and 10 mW/cm^2. Stray radiation was also measured in the eye and testes. The direct-contact applicators produced much less stray radiation than the C- and E-directors. The amount of stray radiation depended on the extent of contact between the applicator and tissue. When the tissue completely covered the applicator aperture, stray radiation was minimal. For the linearly polarized applicator, the intensity of stray radiation was greater in the directions of the E-field vector. Overall, these data indicated that none of the applicators tested would completely meet the proposed safety standards of 5 or 10 mW/cm^2 at a distance of 5 cm from the applicator/skin surface when cylindrical models are used to test compliance.

6621 MORE ON DIATHERMY: ANOTHER POINT OF VIEW. *(Eng)* Felix, W. R. (Vascular Diseases Lab., West Roxbury VA Hosp., Boston, MA); Schuchmann, J. A. *Consum Res Mag* 63(2): 41; 1980 (1 ref).

The effectiveness and hazard potential of different types of diathermy treatment (i.e., microwave [MW], shortwave [SW], and ultrasound [US]) are reviewed. Hazards of MW diathermy include cataract production, electrical interference with demand-type pacemakers, selective heating of effusions and metallic implants with the potential for burning of the adjacent tissue, sterility when applied over the gonads, possible behavioral changes, and possible acceleration of malignant growth when applied over a

neoplasm. Another disadvantage of MW diathermy is that it penetrates poorly through subcutaneous fat and produces very little heating in the deeper muscles where heating may be desired. SW diathermy, which is high frequency electromagnetic current that is converted in the body into heat, has some, but not all, of the side-effects of MW diathermy. SW diathermy produces electrical interference with demand-type pacemakers, selective heating of metallic implants, and possible accentuation of malignant growth when applied over the gonads. SW diathermy penetrates through the subcutaneous tissue rather poorly and is most useful for heating structures relatively close to the skin and for structures covered by only a minimal layer of fat. US diathermy, which is high frequency sound rather than an electromagnetic current, is a much safer and a much more effective deep heating modality than either MW or SW diathermy. US diathermy can be used in the presence of pacemakers and metallic implants and has a definite place in the treatment of patients with musculoskeletal disorders.

6622 A MULTI-CHANNEL SYSTEM FOR MICROWAVE HEATING OF TISSUES. *(Eng)* Hand, J. W. (M. R. C. Cyclotron Unit, Hammersmith Hosp., Du Cane Rd., London W12 0HS, England). *Br J Radiol* 52(624): 984-988; 1979 (11 refs).

A microwave heating system that allows four volumes of tissue to be treated simultaneously is described. The system is particularly useful in experiments involving rodents. The part of the animal to be treated is immersed in a physiologically compatible liquid bolus and is subjected to microwaves (2,450 or 915 MHz) from parallel-opposed waveguide applicators. The temperature of each region treated may be maintained to within approximately ±0.15 C, and thermal gradients in the tissues may be minimized by adjustment of microwave power and liquid bolus temperature. The uniformity of heating in experimental regions is improved by using pairs of applicators in parallel-opposed geometry. To avoid standing wave effects the applicators are energized alternately by means of the control unit. Stray electromagnetic fields are reduced by surrounding the ends of the waveguides and transformers by microwave-absorbing material. At a frequency of 2,450 MHz, the applicators are air-filled and are provided with tuning screws through the broad face of the guide for impedance matching. At 915 MHz the applicators are filled with a low loss dielectric material with a relative dielectric constant of 12. Experiments performed with mouse leg and foot, rat tail, and exteriorized mouse jejunum demonstrated that orientation of the tissue with respect to the microwave electric field does not affect significantly the absorption of microwaves by the tissue. The cooling effect of blood flow within tissue during microwave heating may be reduced from that observed when heating is by immersion in hot water. Although this system is designed for the treatment of experimental animals, the technique of controlled switching of microwave power to a number of applicators should also prove useful in treating patients.

6623 THE SIGNIFICANCE OF ELECTRICALLY STIMULATED OSTEOGENESIS--MORE QUESTIONS THAN ANSWERS. *(Eng)* Becker, R. O. (VA Hosp., Irving Ave. and University Place, Syracuse, NY 13210). *Clin Orthop Relat Res* (141): 266-274; 1979 (37 refs).

Techniques for electrically stimulating osteogenesis are reviewed. With few exceptions, the techniques involve the insertion of various types of electrodes into the marrow cavity of the long bones. Most techniques involve non-unions of fractures of the long bones and utilize direct currents (DC) of various amounts, with the cathode being considered the stimulatory electrode. To obviate most of the problems associated with electrode implantation, one investigator has used a variety of coil systems and magnetic pulses to produce an electrical environment within tissues that he believes is similar to that resulting from DC current delivered by implanted electrodes. From a purely physical viewpoint, however, such a system would produce multiple intermittent circular currents within the tissues, which would not simulate those delivered by an electrode system operating with DC. This magnetic pulse system has produced some interesting results with congenital pseudarthrosis of the tibia, a disease with a high correlation to CNS disturbances and not a typical non-union. This bone regrowth could be considered the result of the pulsed magnetic field acting on the peripheral nerves so as to correct a functional deficiency of some type. The same investigator has also reported that the pulsed field results in a faster rate of healing in acute fractures. Since in this condition the neural electronic system is active, this result can also be interpreted as due to a primary neural effect of the pulsed magnetic field.

6624 MICROWAVE EFFECTS ON GRANULOCYTE AND MACROPHAGE PRECURSOR CELLS OF MICE IN VITRO. *(Eng)* Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ.,Detroit, MI 48202); Ottenbreit, M. J.; Wang, S. L.; Inoue, S.; Bollinger, R. O.; Fracassa, M. *Radiat Res* 80(2): 292-302; 1979 (16 refs).

Colony-forming unit cells in culture (CFU-C) from the femurs and tibias of 2-mo-old C3H mice were exposed to 2,450-MHz continuous wave microwaves in a specially designed fluid-filled waveguide exposure system. The cells were suspended in glass micropipets and were exposed for 15 min to incident power densities of 30-1,000 mW/g² that corresponded to specific absorption rates of 60-2,000 mW/g. No measurable rise in sample temperature was observed, but there was a dose-dependent reduction in

the number of colonies formed by microwave-exposed cells when compared to sham-exposed counter-parts. There was no reduction in the number of colonies formed on days 6 and 12 of culture at 30 mW/cm²; however, as the power was increased up to a level of 500-1,000 mW/cm², there was a corresponding reduction in the number of colonies formed by the microwave-exposed CFU-C. The dose-related colony reduction by CFU-C exposed to microwaves was still evident at days 12 and 14 of culture, indicating that the CFU-C do not recover from the microwave exposure in later culture periods and/or that the CFU-C that form colonies late in the culture period are also affected by microwave exposure. To determine if the reduction in CFU-C was related to sample heating, marrow cells were exposed to three different bath solution temperatures at 7, 22, or 37 C for both microwave (1,000 mW/cm²) and sham treatments. Colony reduction was statistically significant ($p<0.05$) and was similar for all bath temperatures at days 5 and 12. Electron microscopy of microwave-exposed cells indicated no obvious ultrastructural damage to microwave-exposed cells. These observations indicate that 2,450-MHz continuous wave microwaves interacted with murine neutrophil and macrophage precursor cells in a way that was apparently not related to temperature rise. The mode of interaction between microwaves and these precursor cells is not clearly understood.

6625 ELECTROMAGNETIC ABSORPTION IN MULTILAYERED CYLINDRICAL MODELS OF MAN. *(Eng)* Massoudi, H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Barber, P. W.; Iskander, M. F. *IEEE Trans Microwave Theory Tech* 27(10): 825-830; 1979 (11 refs).

The effect of skin-fat-muscle layering and of clothing on the average specific absorption rate (SAR) was investigated in a multilayered cylindrical model of man irradiated by a normally incident electromagnetic plane wave. The effect of layering was generally to change the average SAR values in the frequency range of 0.4-8 GHz. The effects were not considerably large since the greatest increase, which occurred at about 2 GHz, was approximately double that of a homogeneous model, while the greatest decrease, which occurred at about 5 GHz, was approximately half that of a homogeneous model. The location of the layering resonance and the enhancement of the absorption due to layers were found to be almost identical for both planar and cylindrical models. The frequency of the layering resonance was found to be independent of the polarization. For given permittivities of the layers, the layering resonant frequency was inversely proportional to the thickness of the layers. For frequencies below 2 GHz, clothing had very little effect on the SAR value. However, for frequencies between 2 and 8 GHz, some secondary peaks were found in the average SAR values for a model with lossy clothing.

6626 MEASUREMENTS OF COMPLEX DIELECTRIC CONSTANT OF HUMAN SERA AND ERYTHROCYTES. *(Eng)* Bianco, B. (Laboratorio per i Circuiti Elettronici del Consiglio Nazionale delle Ricerche, 16145 Genoa, Italy); Drago, G. P.; Marchesi, M.; Martini, C.; Mela, G. S.; Ridella, S. *IEEE Trans Instrum Meas* IM-28(4): 290-295; 1979 (16 refs).

A method for measuring the complex dielectric constant of biologic liquids at microwave frequencies of 100-2,000 MHz in 50-MHz steps is described. The method is based on a calibration procedure that makes use of three reference fluids having known complex dielectric constants. The sample holder requires no more than 0.5 cm³ of material for the test. Measurements are rapid, so there is no problem of denaturation due to thermal changes. Measurements were made of human erythrocytes, obtaining their inner conductivity using Fricke's equation. Measurements were also made on human sera of normal individuals, tumor patients, chronic hepatitis patients, and myeloma patients. Using an optimization technique, parameters related to the water that is bound to the serum proteins were identified and showed differences possibly related to the presence of certain diseases.

6627 DIELECTRIC PROPERTIES OF BRAIN TISSUE BETWEEN 0.01 AND 10 GHz. *(Eng)* Foster, K. R. (Dept. Bioengineering, D2, Univ. Pennsylvania, Philadelphia, PA 19104); Schepps, J. L.; Stoy, R. D.; Schwan, H. P. *Phys Med Biol* 24(6): 1177-1187; 1979 (20 refs).

Dielectric permittivity and conductivity are reported for grey and white matter from dog brain tissue at 25 and 37 C exposed to microwaves between 0.01 and 10 GHz. Between 0.01 and about 1 GHz, the permittivity decreased and conductivity increased as a power law of frequency. Above 1 GHz, the conductivity increased quadratically with frequency due to dipolar reorientation of free water molecules in tissue. From the quadratic increase in conductivity with frequency above 1 GHz, the apparent rotational relaxation frequency at 37 C was estimated to be 21-24 GHz, which is slightly below the 25 GHz characteristic frequency of pure water at that temperature. The microwave data were analyzed using the Maxwell mixture theory that is applicable for a suspension of nonconducting, low permittivity spheres in bulk water. From the increase in conductivity above 1 GHz and the tissue permittivity of 2-4 GHz, the apparent volume fraction of water was calculated to be approximately 0.70 and 0.55 for grey and white matter, respectively; this is about 10-15% lower than respective values from the literature. This discrepancy is apparently due to a small fraction of water that does not contribute to the tissue permittivity above 1 GHz. Three empirical equations are given to summarize the dielectric properties of average canine brain tissue at 37 C for future theoretical studies of microwave absorption in the head.

6628 ATTEMPTS TO INFLUENCE THE FEEDING BEHAVIOUR OF BROWN RATS USING ELECTROMAGNETISM. *(Eng)* Bohills, S. T. (Rentokil Ltd., Felcourt, East Grinstead, Sussex, England); Leonard, S. P.; Meehan, A. P. *Int Pest Control* 21(5): 114, 116; 1979 (5 refs).

The Sigma electro-energy rodent control unit, which is claimed by the Orgolini Manufacturing Company, Sparks, Nevada, USA to be effective over an area of 1-2 acres, was tested for its ability to influence the feeding behavior of wild *Rattus norvegicus*. The test was conducted in a 17 m by 17 m outdoor pen that containcd between 100 and 150 rats in a natural environment of burrows in soil with well established runs. The machine was located in one corner of the pen, conforming closely to the manufacturer's instructions. Twenty feeding points were then established as a series of five arcs radiating out from the Sigma machine at 4-m intervals. After a 3-wk pretreatment period, the unit was switched on for a period of 5 wk, and food consumption at each of the feeding points was recorded daily. Total food consumption in the pen was steady over the pretreatment period and remained so during the treatment period. No decrease in total food consumption was observed. During the experiment, there was also no obvious shift in the number or distribution of open rodent burrows across the pen. It is concluded that the device had no measurable effect on the distribution or level of feeding in the test pen, nor did it prevent rats from reproducing.

6629 BEHAVIORAL EFFECTS OF STRONG 60-Hz ELECTRIC FIELDS IN RATS. *(Eng)* Smith, M. T. (Dept. Bioengineering, Univ. Utah, Salt Lake City, UT 84112); D'Andrea, J. A.; Gandhi, O. P. *J Microwave Power* 14(3): 223-228; 1979 (9 refs).

The effect of a 5-wk exposure to a 25 kV/m, 60-Hz electric field on body mass, food and water intake, and exploratory activity of male Long Evans rats was investigated. Eight individually housed rats were raised, beginning at age 30 days, for 6 wk in an electric field exposure apparatus. The 1st wk consisted of an initial baseline period that was followed by 5 wk of exposure to the high voltage field. A vertical plate system was used such that the long axis of the rat was parallel to the electric field for the majority of the time. This orientation can result in a zone of field enhancement close to the animal's head and has the advantage that it approximates the relationship of man to the electric field of overhead power lines. A similar population of rats housed in an identical environment, except for the absence of the high voltage field, was used as a control group. A repeated measures analysis of variance showed that the effects of the high voltage field were negligible ($p>0.05$) on body mass, food consumption, and water intake. The exposure by trials interactions for all three data sets were also negligible ($p>0.05$). In no case during the 6-wk study period were the experimental rats observed to be disturbed in the electric field by hair stimulation or shocks from the drinking tubes. A two-tailed "T" test of the results of the exploratory activity measurements revealed no significant difference ($p>0.05$) between the experimental group and the control group. Further study is necessary to determine any possible behavioral changes that may have been induced by field enhancement.

6630 SURVIVAL OF RATS INJECTED WITH ACETYLCHOLINE, EPINEPHRINE, HISTAMINE, OR SEROTONIN AND EXPOSED TO ACUTE MICROWAVES. *(Pol)* Mikolajczyk, H. (Instytut Medycyny Pracy, ul. Teresy 8, 90-950 Lodz, Poland); Holwek, A. *Patol Pol* 30(1): 127-133; 1979 (10 refs).

The effects of microwave irradiation with 2,680-2,880 continuous waves (power density of 120 mW/cm^2) on the survival time of 145 Wistar rats who had received either single or multiple doses of hormones were studied. In the first experiment, the hormones were injected intravenously in starch gel 10 min before irradiation; the doses were: acetylcholine, 1 mg or 1 mg/day for 10 consecutive days; epinephrine, 0.1 mg or 0.05 mg/day for 10 consecutive days; histamine, 20 mg or 2.5 mg/day for 10 consecutive days; and serotonin, 2 mg or 0.5 mg/day for 10 consecutive days. In another experiment, the hormones were irradiated prior to administration (1 mg acetylcholine, 0.1 mg epinephrine, 20 mg histamine, and 2 mg serotonin). The average survival time of the rats that were irradiated only was 28.8 min. The average survival times of animals treated with single dose of acetylcholine, epinephrine, histamine, and serotonin were 33.3 min ($p<0.05$), 24.4 min, 26.2 min, and 2.45 min ($p<0.05$), respectively. The average survival times in the animals receiving 10 injections were 31.4 min, 25.7 min, 30.3 min, and 27.1 min, respectively. After single injections of irradiated hormones, the average survival times were 27.4 min for acetylcholine-treated animals, 23.2 min ($p<0.05$) for epinephrine, 22.1 min ($p<0.05$) for histamine, and 26.4 min for serotonin. Lung edema, rare in the other experimental animals and controls, was observed in 9/10 irradiated animals receiving a single dose of epinephrine or 10 doses of serotonin. After in vivo irradiation, epinephrine was transformed into another substance, indicated by a color change from a clear to a pink compound. The findings indicate a possible link between changes in the effects of certain neurohormones, especially hot spots, and functional neurologic disorders in subjects exposed to microwaves.

6631 HETEROGENEITY OF THE REACTIONS OF NEURONS FROM DIFFERENT PARTS OF THE BRAIN TO REPEATED SHF IRRADIATION. *(Rus)* Galkina, N. S. (Dept. Histology and Embryology, I. P. Pavlov Riazan' Medical Inst., Riazan', USSR); Ukhov, Iu. I *Zh Nevropatol Psikhiatr im SS Korsakova* 79(7): 880-884; 1979 (10 refs).

The effects of super high frequency (SHF) irradiation (40-50 mW/cm², 30 min/day for 10 consecutive days; frequency and other data not given) on neurons from different parts of the brain were studied in 35 adult male rats. Two other rats served as untreated controls. The animals were decapitated immediately or 1-30 days after the last irradiation. Immediately after the irradiation, moderate swelling and chromatolysis of the neurons, hypochromia, slight vacuolization of the cytoplasm, and partial loss of ribonucleic acid were seen in the majority of the cerebral formations examined. The swelling of the cytoplasm was accompanied by a swelling of the nuclei. The dystrophic changes were most pronounced and steady in neurons of the parietal region and least marked in the neurons of the frontal region and in the reticular formation. Disproportionate nuclei swelling and chromatolysis were observed in the optic thalamus, which is indicative of the activation of protein synthesis processes. The recovery processes started 5 days after the last irradiation, mainly in the neurons of the reticular formation. Large lumps of basophilic substance, located mainly in the perinuclear zone, were found in some neurons after 1 mo. The residual swelling persisted longest (up to 1 mo) in the neurons of the ganglionic layer of the parietal region.

6632 STUDY OF BRAIN METABOLISM USING RAPID MICROWAVE HEATING. *(Eng)* Stavinoha, W. B. (Univ. Texas Health Science Center, San Antonio, TX). *Psychopharmacol Bull* 15(4): 63; 1979 (no refs).

Either 914 MHz or 2,450 MHz microwave irradiation was used to rapidly inactivate mouse and rat brain enzymes in an effort to study brain neurochemistry and metabolism. Microwave irradiation abolished cholinesterase and choline acetyltransferase activity. In the rat brain, a frequency of 914 MHz produced a more rapid uniform enzyme inactivation than 2,450 MHz microwaves. Inactivation of mouse brain adenylate cyclase, guanylate cyclase, and cyclic nucleotide phosphodiesterase was uniform and complete after 300 msec of 6 kW microwave irradiation. Levels of the intermediary metabolites adenosine triphosphate, adenosine diphosphate, adenosine monophosphate, phosphocreatine, pyruvate, and lactate in rat brains after 0.6 sec of microwave irradiation at 2,450 MHz reflected the uniformity of tissue inactivation achieved. Dopamine levels in mouse brain after sacrifice by microwave irradiation increased only in the corpus striatum.

6633 MICROWAVE-EVOKED BRAINSTEM POTENTIALS IN CATS. *(Eng)* Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ., Detroit, MI 48202); Meltzer, R. J.; Redding, F. K. *J Microwave Power* 14(3): 291-296; 1979 (16 refs).

Microwave-evoked brainstem potentials were investigated in 12 cats. When short rectangular microwave pulses (pulse duration, 0.5-25 μsec; pulse repetition rate, 10-100/sec; peak incident power, 10 kW) produced by a pulsed-signal source at 2,450 MHz were applied to the dorsal and frontal surface of the cat head, via a small (15 mm in diameter) Elmed direct-contact diathermy applicator, the summed potentials evoked from the vertex, medical geniculate, inferior colliculus, lateral lemniscus, and superior olive were similar to those evoked by acoustic pulses presented binaurally at a rate of 10-100/sec at about 70 db above threshold sound level. However, the microwave-evoked responses were always seen immediately following delivery of the stimuli, without the familiar transmission delay associated with acoustic waves that must travel at a much slower rate through the hollow ear bars. At a constant peak power and pulse duration, the amplitude of potentials at the vertex decreased with increasing pulse repetition frequency. Reduction of the stimulus intensity (peak power) while holding the pulse duration and pulse repetition rate constant was accompanied by a reduction in amplitudes of all responses at the vertex. Increasing the pulse duration increased the amplitude of the responses at the vertex to a plateau, with subsequent oscillation in some cases. Successive coagulative lesions of the inferior colliculus, lateral lemniscus, and superior olive produced characteristic changes in the evoked-potential wave forms, indicating the possibility that microwave pulses might be used to achieve an estimate of sensory-neural involvement in the objective evaluation of hearing and to assess the presence of space-occupying lesions in patients with neurologic disorders.

6634 CURRENT STATUS OF MICROWAVE EFFECTS ON THE BLOOD-BRAIN BARRIER. *(Eng)* Albert, E. N. (Dept. Anatomy, George Washington Univ. Medical Center, Washington, DC 20037). *J Microwave Power* 14(3): 281-285; 1979 (25 refs).

Three categories of studies investigating the effect of microwave radiation on blood-brain barrier permeability are reviewed. The first category consists of studies where animals received intravenous injections of sodium-fluorescein dye that was detected either visually or fluorometrically in brain sections or homogenates. In these studies, 30 min of continuous wave (CW) microwave (1,200 MHz) irradiation of rats with an average power density of 2.4 mW/cm² resulted in a statistically significant increase of fluorescein in brain slices of experimental animals over controls. Similar but heightened alterations in the permeability of this barrier were observed when rats were irradiated with pulsed microwaves (modulated at 2.1 mW/cm² peak and 0.2 mW/cm² average power density). A second category of studies used light and electron microscopic tracers

to identify geographic locations as well as mechanisms underlying changes in brain microvasculature permeability for larger molecules. In these studies, irradiation of unanesthetized Chinese hamsters in the far field with 2,450 MHz CW microwaves at 10 mW/cm² resulted in increased extravasation of the tracer protein horseradish peroxidase in the brains of almost 35% of the experimental animals. It was also observed that the leaky microvasculature and surrounding neuropil represented focal and not disseminated lesions. Similar studies with rats who were placed in the near field and irradiated with 2,800 MHz microwaves at 10 mW/cm² for 2 hr produced results identical to those observed in hamsters. Further tests with hamsters and rats indicated that the blood-brain barrier lesions inflicted by microwaves were reversible. In a third category of studies, rats were exposed to 1.3 GHz CW or pulsed microwaves for 20 min and tested for the passage across the blood-brain barrier of polar isotopes of differing molecular weights. Mannitol and inulin were found to enter the brain from the blood in significantly greater amounts in the hypothalamus, cerebellum, and medulla in microwave-irradiated animals. The permeability of mannitol was found to be very much dependent on power density, pulse width, and number of pulses/sec. However, two subsequent and independent investigations using similar variables failed to confirm the above results. Overall it appears that the effects of low power microwaves on the blood-brain barrier are still controversial.

6635 INFLUENCE OF VISION OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS: INDUSTRIAL MEASUREMENTS, MAGNETOPHOSPHENE STUDIES IN VOLUNTEERS AND INTRARETINAL STUDIES IN ANIMALS. *(Eng)* Lovsund, P. (Dept. Biomedical Engineering, Univ. Hosp., S-581 85 Linkoping, Sweden Medical Res. Council); Oberg, P. A.; Nilsson, S. E. *Acta Ophthalmol* 57(5): 812-821; 1979 (5 refs).

The effect of extremely low frequency electromagnetic fields on vision were examined after measurements were made of the fields that were generated by strong electric currents used for heating purposes in the welding and steel industry. Industrial measurements of fields generated by welding and steel processes (arc and resistance welding, electroslag refining, and electric steel furnaces) indicated that these fields had a frequency of 0-50 Hz and a magnetic flux density of 0.1-10 millitesias (mT). In subsequent experiments, electromagnetic fields with a frequency of 10-50 Hz and a magnetic flux density of 0-40 mT were used to induce magnetophosphenes in human volunteers. The threshold values varied with the frequency of the magnetic field and the luminance level of the background light. In virtual darkness there was a sensitivity maximum at 30 Hz. At higher luminances this sensitivity maximum moved to lower frequencies (20-25 Hz), and a second maximum appeared at about 40-45 Hz. The maxima were separated by a local sensitivity minimum at 30-35 Hz. Differences in threshold values were observed between volunteers with normal color vision and those with defective color vision. In a final experiment, a frog retina was exposed to extremely low frequency fields (10-50 Hz) at magnetic flux densities of 0-80 mT. Retinal activity induced by the fields was registered from the ganglion cell layer by means of a microelectrode technique. The results indicate that magnetophosphenes are generated in the retina and are in the same channels that are normally propagating signals induced by light of different qualities.

6636 EFFECTS OF LOW LEVEL MICROWAVE RADIATION ON THE DIGESTIVE TRANSIT OF THE RAT. *(Eng)* Santini, R. (Lab. Physiology-Pharmacodynamy, Natl. Inst. Applied Sciences, 69621 Villeurbanne cedex, France); Deschaux, P.; Jacomino, J. M.; Pellissier, J. P. *J Microwave Power* 14(3): 287-289; 1979 (9 refs).

The effect of low-level microwave radiation (3-4 mW/cm², 2,450 MHz) on digestive transit in female Wistar rats was investigated. Three groups of eight rats were used: a control group, a group exposed to microwaves for 4 hr, and a group exposed to microwaves for 8 hr. After irradiation, experimental animals and controls received per os a digestive transit marker (arabic gum saturated with active charcoal). Digestive transit was not affected by 4 hr of microwave exposure; however, after an 8-hr exposure, a significant ($p<0.001$) acceleration of digestive transit was observed. This acceleration was still observed 24 hr after microwave exposure ($p<0.001$). The transit length (cm for 100 cm of intestine) for controls, the 4-hr group, and the 8-hr group was 43.62 ± 5.47, 50.60 ± 7.65, and 58.83 ± 3.76, respectively. The rectal temperatures of controls and rats irradiated for either 4 or 8 hr were not significantly different, being 37.95 ± 0.63, 37.78 ± 0.19, and 37.66 ± 0.26 C, respectively, when measured 60-90 sec after irradiation. It is suggested that the duration of the microwave accelerating effect (above 24 hr) on digestive transit after 8 hr of irradiation excludes a biochemical mechanism. It is postulated that a superconductive mechanism may affect nerve function (e.g., vagus nerve), thus interfering with digestive transit.

6637 MICROWAVES: EFFECT ON THERMOREGULATORY BEHAVIOR IN RATS. *(Eng)* Stern, S. (Dept. Radiation Biology, Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14642). *Science* 206(4423): 1198-1201; 1979 (24 refs).

The effect of 2,450-MHz continuous wave microwaves on the thermoregulatory behavior of male Long-

Evans hooded rats was investigated. Six rats, with their fur clipped, pressed a lever to turn on an infrared lamp while in a cold chamber. When they were exposed to microwaves for 15-min periods, the rate at which they turned on the infrared lamp decreased as a function of the microwave power density, which ranged between 5 and 20 mW/cm^2. This result indicates that behaviorally significant levels of heating may occur at an exposure duration and intensities that do not produce measurable changes in other behavioral measures or in colonic temperature.

6638 THE EFFECT OF ENVIRONMENTAL TEMPERATURE AND AVERAGE DOSE RATE OF MICROWAVE RADIATION ON THE OXYGEN-CONSUMPTION RATE OF MICE. *(Eng)* Ho, H. S. (BRH, FDA, 5600 Fishers Lane, Rockville, MD 20857); Edwards, W. P. *Radiat Environ Biophys* 16(4): 325-338; 1979 (15 refs).

The oxygen consumption rate of CF1 male mice (3-mo-old) was determined before, during, and after sham and microwave (2,450 MHz, continuous wave) irradiation at environmental temperatures of 20, 24, 30, and 35 C and at a relative humidity of 55% and an air flow rate of 78 ml/min. The mice were exposed for 30 min to five forward power levels ranging from 0.09 to 3.3 W, which resulted in corresponding average dose rates of 1.2-45.1 mW/g. Values of oxygen consumption rate were converted to values of specific metabolic rate (SMR) in mW/g. Among sham-irradiated mice, those treated in an environmental temperature of 30 C had the lowest SMR value of 15.0 mW/g during the sham-irradiation stage and 13.1 mW/g during the sham-postirradiation stage. Relatively high (>10 mW/g) microwave dosing of mice in environmental temperatures of 20 and 24 C caused in some cases a decrease in the SMR value relative to sham-irradiated controls in the same environmental temperatures. However, these decreased SMR values were not lower than the SMR values of sham-irradiated mice in an environmental temperature of 30 C. At 35 C, dosing with high level microwave radiation caused the SMR values of mice to be higher than the sham value. A possible trend to increased SMR values during and after relatively low level (1.6 mW/g) microwave irradiation was observed at environmental temperatures of 24 and 30 C, suggesting that further experiments should be performed to detemine possible effects of low-level microwave radiation on SMR.

6639 NATIONAL RADIO SCIENCE MEETING BIOELECTROMAGNETICS SYMPOSIUM HELD JUNE 18-22, 1979 IN SEATTLE, WASHINGTON. *(Eng)* Postow, E., ed. United States Natl. Committee (Natl. Academy Sciences, 2101 Constitution Ave., NW, Washington, DC 20418). Sponsored by the United States Natl. Committee, International Union Radio Science, International Symposium Antennas Propagation Society, Inst. Electronics Electrical Engineers. (Washington, DC). 503 pp.; 1979 (no refs).

Over 150 abstracts of papers delivered to the National Radio Science Meeting Bioelectromagnetics Symposium held June 18-22, 1979 are presented. The material in this symposium covers both continuous and pulsed electromagnetic fields over the frequency range of 0 Hz (direct current) to the microwave spectrum. Topics discussed include the following: methods for studying the interaction of electromagnetic fields with biologic materials; bioeffect studies concerning metabolism, the nervous system, the cardiovascular system, hormones, the blood-brain barrier, prenatal exposure, growth and development, bone growth stimulation, tumor growth, the induction of cataracts, and mutagenic effects; measurements of radio frequency power absorption in phantom models; far-field microwave dosimetry; tissue impedance and dielectric measurements; the design of temperature probes and monitors for microwave bioeffects research; measurements of electric and magnetic field strengths from industrial sources; the design and evaluation of microwave diathermy applicators; specific absorption rate measurements and waveguide dosimetry studies; the effects of microwaves at the cellular level; and the effects of electromagnetic nonionizing radiation on behavior, learning, and performance.

6640 A NEGATIVE TEST FOR MUTAGENIC ACTION OF MICROWAVE RADIATION IN *DROSOPHILA MELANOGASTER*. *(Eng)* Hamnerius, Y. (Res. Lab. Electronics, Chalmers Univ. Technology, Goteborg, Sweden Engineering Sciences); Olofsson, H.; Rasmuson, A.; Rasmuson, B. *Mutat Res* 68(3): 217-223; 1979 (19 refs).

The possible mutagenic action of 2,450 MHz continuous wave (CW) microwave radiation was investigated in *Drosophila melanogaster* embryos by measuring the frequency of somatic mutations for eye pigmentation. Embryos 1- to 2-hr old were exposed in water for 6 hr to microwave radiation at an average specific absorption rate of 100 W/kg. The radiation was generated by a CW magnetron capable of delivering powers up to 1 kW. The spontaneous mutation frequency (males with red eye sectors) for the microwave-irradiated embryos was 0.05%, which was not significantly different from a value of 0.06% for nonirradiated controls. Tests with two sets of positive controls showed that this unstable test system was sensitive to ionizing radiation and to chemical mutagens of the alkylating type. Microwave irradiation also failed to affect the survival of *Drosophila* embryos.

6641 LACK OF MICROBIAL GENETIC RESPONSE TO 2.45-GHz CW AND 8.5- TO

9.6-GHz PULSED MICROWAVES. *(Eng)* Dutta, S. K. (Dept. Botany, Howard Univ., Washington, DC 20059); Nelson, W. H.; Blackman, C. F.; Brusick, D. J. *J Microwave Power* 14(3): 275-280; 1979 (16 refs).

Strain D4 of the yeast *Saccharomyces cerevisiae* and strains TA-1535, TA-100, and TA-98 of the bacterium *Salmonella typhimurium* were exposed to 2.45 GHz continuous wave microwave radiation at a power density of 20 mW/cm² (specific absorption rate, 40 W/kg) or to 8.5-9.6 GHz pulsed X-band radiation (pulse repetition rate, 1,000 Hz; duty cycle, 0.001) at power densities of 1-45 mW/cm² to test the mutagenic potential of microwaves. The yeast suspensions were exposed for 2 hr to 2.45 GHz radiation at 30.0 ± 0.5 C and to X-band radiation at 29.0 ± 0.5 C. The bacteria were exposed for 90 min at 37.0 ± 0.5 C to 2.45 GHz radiation and at 35.0 ± 0.5 C to X-band radiation. The studies revealed no increase in mutations or in mitotic gene conversions. Decreased viability of cells was noted in all cultures tested after irradiation at power densities of 30 mW/cm² or more; however, this appeared due primarily to heating.

6642 EFFECTS OF HYPOPHYSECTOMY AND DEXAMETHASONE ON RAT ADRENAL RESPONSE TO MICROWAVES. *(Eng)* Lotz, W. G. (Biomedical Div., Naval Aerospace Medical Res. Lab., Naval Air Station, Pensacola, FL 32508); Michaelson, S. M. *J Appl Physiol* 47(6): 1284-1288; 1979 (14 refs).

To determine which organizational level of the adrenal axis is stimulated by microwave exposure male Long-Evans rats were either acutely hypophysectomized or pretreated with dexamethasone (DEX) and then exposed to 2,450-MHz microwaves amplitude modulated at 120 Hz. In the first set of experiments, circulating corticosterone (CTS) levels were measured to compare the adrenocortical response to acute microwave exposure of normal, hypophysectomized, or sham-hypophysectomized rats. Plasma CTS levels in acutely hypophysectomized rats exposed to 60 mW/cm² of microwave radiation for 60 min were below control levels, indicating that the microwave-induced CTS response observed in normal, intact rats is dependent on adrenocorticotropic hormone secretion by the pituitary. In another set of experiments, rats pretreated with DEX before receiving microwaves for 60 min at a power density of 50 mW/cm² showed complete suppression of the CTS response to microwaves at DEX doses of ≥3.2 μg/100 g body wt. However, the CTS response to a 70-mW/cm² exposure was only partially suppressed by prior administration of 3.2 or 5.6 μg/100 g body wt DEX. These findings and the results of other previously reported experiments are consistent with the hypothesis that the stimulation of the adrenal axis in the microwave-exposed rat is a systemic, integrative process due to a general hyperthermia.

6643 COMMENTS ON OBSERVATIONS OF MOUSE FETUSES AFTER IRRADIATION WITH 2.45 GHz MICROWAVES BY E. BERMAN *et al.* [LETTER TO EDITOR]. *(Eng)* Grendon, A. (2807 Sheridan Way, Sacramento, CA 95821). *Health Phys* 37(3): 423; 1979 (1 ref).

Comments are made on an article entitled "Observations of Mouse Fetuses after Irradiation with 2.45 GHz Microwaves " (E. Berman, *et al*, *Health Phys* 37, 1979). The author contends that a more accurate conclusion would state that the exposures were probably embryopathic in mice. It is pointed out that the physical effect of microwave radiation diminishes rapidly as it passes through a conductive material. While the conductive tissues of the mother offer little shielding to the fetus in the case of the mouse, the shielding effect is large in the case of a human mother. Thus, it is considered highly improbable that the embryopathic effects in mice observed at 28 mW/cm² of 2.45-GHz radiation would be observed in humans at the same power density.

6644 EFFECT OF EXPERIMENTAL MAGNETIC STORM ON THE PRODUCTION OF LAMBDA PHAGE. *(Eng)* Chervinets, V. M. (Kalinin Medical Inst., ul. Sovetskaia 4, Kiev, USSR). *J Hyg Epidemiol Microbiol Immunol (Praha)* 23(3): 261-265; 1979 (14 refs).

Effects on the production of lambda phage induced by the vertical component of a fluctuating magnetic field (MF) that changed by ±0.1 Oe against the value of the geomagnetic field every 3 min for a 24-hr period were investigated. Standard cultures of lysogenic *Escherichia coli* (*E. coli*) K = 12 bacteria and the streptomycin-resistant indicator strain *E. coli* C = 85 (*E. coli* C-85 Smr) were used as the test organisms. Production of free phage was tested by inoculating the cultures of lysogenic and indicator bacteria with 800 μg/ml of streptomycin. The experimental results demonstrated that both the lysogenic system of *E. coli* K = 12 lambda and the indicator strain *E. coli* C = 85 Smr react to small changes in the intensity of the geomagnetic field. The fluctuating MF inhibited phage production in the lysogenic system and produced morphologic peculiarities in negative phage colonies and changes in phage susceptibility of the *E. coli* indicator strain.

6645 EVIDENCE THAT GEOMAGNETIC VARIATIONS CAN BE DETECTED BY LORENZINIAN AMPULLAE. *(Eng)* Brown, H. R. (Pavlov Inst. Physiology, Acad. Sciences USSR, Leningrad, USSR); Ilyinsky, O. B.; Muravejko, V. M.; Corshkov, E. S.; Fonarev, G. A. *Nature* 277(5698): 648-649; 1979 (9 refs).

Direct neurophysiologic evidence is presented that telluric currents produced by geomagnetic variations

can be detected by Lorenzinian ampullae of skates. Experiments were performed on Barents Sea skates (*Raja radiata*) in Dalnje-Zelenetsk Bay on the Barents Sea. Single-unit activity was recorded from nerve fibers supplying the ampullae of Lorenzini of the hyoid ampullary group. The electrical state of the sea was monitored using two silver-silver chloride electrodes 400 m apart, parallel with the coastline. These two electrodes were connected by a marine cable to similar electrodes in an experimental tank. To estimate the electroreceptor unit response to the natural stimulus, spike frequency was compared to the magnitude of the voltage gradients produced by telluric currents. Magnetic field variations were registered. Measurements were made during a magnetic substorm that appeared together with the polar light on February 25-26, 1978. Electric field oscillations due to geomagnetic variations produced a clear-cut response in the electroreceptors as judged by corresponding changes in spike frequency. The spike frequency was sensitive not so much to the absolute value of the electric field as to its rate of change. Receptor sensitivity was sufficient to detect a change in the elecric field as small as 0.006 μV/cm/sec. These measurements clearly indicate that the ampullae of Lorenzini can detect the electric field induced by variations of the earth's magnetic field.

6646 POSSIBLE INFLUENCE OF ELECTROMAGNETIC FIELDS ON THE FUNCTION OF PACEMAKERS. *(Cze)* Musil, J. (Institut hygieny a epidemiologie, Srobarova 48, Prague 10, Czechoslovakia). *Prac Lek* 31(6/7): 255-256; 1979 (11 refs).

The susceptibility of 23 different cardiac pacemaker models from 11 manufacturers to electromagnetic fields (frequency 450-3,200 MHz, pulse length 0.01-20 msec, field intensity up to 1,200 V/m, or 35 kHz-9 GHz, pulse length 1-2,000 μsec, 0.02-32 MW) was studied in technical tests. The investigations demonstrated the considerable influence of the frequency, pulse length, and field strength on the function of the pacemakers, and also considerable differences in the susceptibility of different models of the same manufacturer and from one manufacturer to another. The interference threshold was found to be at 10 V/m, but it was considerably higher in the most modern units (250 V/m). The interference increased with increasing pulse length and decreasing frequency. Frequencies higher than 5 GHz caused no interference.

6647 LINAC MICROWAVE HAZARDS TO CARDIAC PACEMAKER WEARERS [LETTER TO EDITOR]. *(Eng)* Annett, C. H. (Dept. Physics and Astronomy, Univ. Kansas, Lawrence, KS 66045). *J Microwave Power* 14(3): 297; 1979 (1 ref).

Microwave leakage levels were made on a Siemens Mevatron VI linac and a Varian Clinac 18 linac at two different hospitals to assess the potential hazard of microwave-induced cardiac pacemaker failure in cancer patients treated with linacs. Both linacs operated at S-band microwave frequencies. Some low-frequency radiation of a few megahertz was produced by both linacs, presumably by the thyratron tubes. However, no microwave leakage was found, either at the fundamental frequency or at the second harmonic, for either linac. Field-strength measurements showed that the low-frequency radiation was well below the threshold level (5 mW/cm^2) for pacemaker damage. This experiment indicates that there is apparently no microwave hazard to pacemaker-equipped patients.

6648 PERFORMANCE OF X-RAY MEASUREMENT INSTRUMENTS WHEN SUBJECTED TO ENVIRONMENTAL LEVEL RF FIELDS. *(Eng)* Frazier, J. R. (BRH, FDA, Rockville, MD 20857); Ohlhaber, T. R.; Ruggera, P. S. *HEW Publication (FDA)* 78-8065 8 pp.; 1978 (5 refs).

The performance of eight x-ray detection/measurement instruments was investigated in the presence of radio frequency fields ranging from 10 to 200 MHz in frequency at power densities of 0.07-13.0 μW/cm^2. The specific performance capabilities monitored include instrument response to gamma irradiation, consistency of readings, and zero drift. No adverse effects of RF fields on x-ray measurement were seen at power densities $\leq$13 μW/cm^2 and frequencies of $\leq$110 MHz for a Technical Associates Model TBM-1 Geiger-Mueller Ratemeter, a Victoreen Model 499 "Vic-Chek" Geiger-Mueller Survey Meter, and a Victoreen Model 440 RF/C Radiation Exposure Rate Measuring System. In experiments with a Victoreen Model 555 Radocon II Integrating Ratemeter, the instrument zero could not be properly adjusted over the entire frequency range under investigation; thus, no further attempts to check the instrument's performance were made. X-ray exposure readings were either higher or lower than their true values in the presence of the radio frequency fields under investigation for the following four instruments: a Victoreen Model 687-C Minometer II Charger-Reader with Model 239-A Ionization Chamber, a Victoreen Model 666 Fluoroscopic Survey Meter, an MDH Model 1015-F x-Ray Monitor, and a Victoreen Model 660 Survey Meter. These results indicate that x-ray exposure and/or exposure rate meters of the ionization chamber type, though superior for precise radiation measurement, are susceptible to environmental level radio frequency fields.

6649 MICROWAVE TIME DELAY SPECTROSCOPIC IMAGERY OF ISOLATED CANINE KIDNEY. *(Eng)* Jacobi, J. H. (Dept.

Microwave Res., Walter Reed Army Inst. Res., Washington, DC 20012); Larsen, L. E. *Med Phys* 7(1): 1-7; 1980 (8 refs).

A method for producing microwave images, which are improved through the reduction of multipath propagation effects, is described that employs water-immersed antennas and microwave time delay spectroscopy at S-band. The method uses a transmitted signal whose amplitude is constant but whose frequency varies with time in a linear function. The microwave frequency is varied from 3,143 to 3,763 MHz by applying a ramp function to the external frequency modulation input of a sweep oscillator. The principal advantage of the technique is that it allows selective analysis of time delay and attenuation of the direct path that connects the transmitting and receiving antennas. Thus, image contamination due to multipath propagation can be reduced. It is shown that objects as small as 6 mm in diameter can be detected and that objects 10 mm apart appear as separate responses on the image. It is also shown that it is possible to generate a physiologically and anatomically relevant image of an isolated canine renal specimen.

6650 WATER CONTENT IN TISSUES OF RATS TREATED WITH NEUROHORMONES AND IRRADIATED IN MICROWAVE FIELD UNTIL THERMAL DEATH. *(Pol)* Mikolajczyk, H. (Instytut Medycyny Pracy, ul. Teresy 8, 90-950 Lodz, Poland). *Patol Pol* 30(1): 119-125; 1979 (4 refs).

The water content (%) of the submaxillary salivary glands, thigh muscle, and skin of 205 adult male Wistar rats was determined in controls and after microwave irradiation with 2,680-2,880 MHz continuous waves (incident power density of 120 mW/cm² until death) and/or the injection of hormones. In two experiments, rats were irradiated with microwaves and injected intraveneously with either single or multiple doses of hormones: acetylcholine, 1 mg or 1 mg/day for 10 consecutive days; epinephrine, 0.1 mg or 0.5 mg/day for 10 consecutive days; histamine, 20 mg or 2.5 mg/day for 10 consecutive days; or serotonin, 2 mg or 0.5 mg/day for 10 consecutive days. In a third experiment the hormones were irradiated in vitro 10 min prior to injection; the hormone doses were 1 mg of acetylcholine, 0.1 mg of epinephrine, 20 mg of histamine, and 2 mg of serotonin. The water content of control animals was 74.7% in the submaxillary salivary glands, 75.9% in the thigh muscle, and 63.4% in the skin. Irradiation with microwaves after the administration of hormones modified the typical effect that these hormones have on the water content of the salivary glands, thigh muscle, and skin. In rats that received microwave irradiation only, the water content was 75.8%, 73.3%, and 65.5%, respectively. The water content was significantly increased in animals irradiated after a single hormone dose: 81.3% with acetylcholine and 81.8% with epinephrine in the submaxillary salivary glands, 75.1% with epinephrine and 74.5% with serotonin in the thigh muscle, and 60.7% with histamine and 61% with serotonin in the skin. Compared with single-doses, repeated administration of epinephrine, histamine, and serotonin before irradiation increased the water content in the submaxillary salivary glands. In vitro irradiation of the hormones prior to injection caused changes in their effects on the water content of these tissues. The water content in the submaxillary salivary glands was 71.4% after irradiated histamine administration and 72.2% after serotonin. In the thigh muscle, the water content after the administration of irradiated epinephrine, histamine, and serotonin was 74.8%, 74.4%, and 74.5%, respectively. In the skin, the water content after the administration of irradiated acetylcholine, histamine, and serotonin was 60%, 62.4%, and 58.5% respectively.

6651 THE ROLE OF WATER IN MICROWAVE ABSORPTION BY BIOLOGICAL MATERIAL WITH PARTICULAR REFERENCE TO MICROWAVE HAZARDS. *(Eng)* Dawkins, A. W. (Physics Dept., Queen Elizabeth Coll., London W8 7AH, England); Nightingale, N. R.; South, G. P.; Sheppard, R. J.; Grant, E. H. *Phys Med Biol* 24(6): 1168-1176; 1979 (21 refs).

Absorption of the energy of plane electromagnetic radiation by an aqueous solution of macromolecules was examined using a simplified model for the hydrated molecule that consisted of a spherical shell of bound water surrounding a spherical core. The analysis was carried out for a macromolecule of a 5-nm radius surrounded by a hydration shell of width corresponding to two water molecules, although the theory is valid up to a radius of at least 10^{-7} m. The power deposition per unit volume of the shell was calculated in the frequency range of 100 MHz to 100 GHz for several bound water relaxation frequencies. In each case the corresponding values were also calculated for free water. The values obtained for the bound water were significantly higher than those for free water up to frequencies of at least 1 GHz. In the microwave region, the absorbed power density in the bound water shell surrounding the macromolecule was at least five times greater than if the shell were composed of free water. The frequency at which the maximum difference occurred between these values for bound water and free water corresponded approximately to the bound water relaxation frequency. Because of the strong coupling between bound water molecules and macromolecules present in biologic material, the above finding could be a significant factor in explaining the biologic effects of microwaves at the molecular level.

6652 THE MAGNETIC BLUEPRINT OF LIFE. *(Eng)* Davis, A. R. (No affiliation given);

Rawls, W. C. (Hicksville: Exposition Press): 158 pp.; 1979 (263 refs).

Relationships between magnetism and human health are discussed from the standpoint of finding more natural methods of health, healing, and happiness. The following topics are presented as separate chapters: evolution with natural magnetism, the nature of the universe, the effects of negative versus positive ions on the human nervous system, radiation dangers, the art of magnetic healing, the future of biomagnetics, food and nutrition, and water, humidity, and moisture.

6653 EFFORTS BY THE ENVIRONMENTAL PROTECTION AGENCY TO PROTECT THE PUBLIC FROM ENVIRONMENTAL NONIONIZING RADIATION EXPOSURES. *(Eng)* General Accounting Office (Community and Economic Development Div., Washington, DC 20548). [available through National Technical Information Services, Springfield, VA 22161. Document No. PB-279 483]; 15 pp.; 1978 (no refs).

EPA activities in the area of environmental nonionizing radiaion (10 MHz-300 GHz) are reviewed. Although EPA efforts to detect and evaluate biologic effects of nonionizing radiation have not yet been able to generate a sufficient data base on which quantitative and scientifically sound radiation protection standards for microwave and other nonionizing frequencies can be established, EPA is finding preliminary results that low-level exposures may affect the immune system, create anomalies in mouse litters such as hernias of the brain, and produce a trend to lowered behavioral performance. Although the significance of these preliminary results is still being evaluated, EPA officials agree that to dismiss the Soviet observations of low-level effects would be a mistake. In the area of monitoring, EPA is currently obtaining data on environmental levels of radio frequency and microwave radiation in United States urban areas. As of February 1978, EPA had collected measurements in 11 metropolitan areas and will continue similar studies in Denver, Los Angeles, San Francisco, and Seattle during the next 18 mo. The highest levels measured were about 150 $\mu W/cm^2$, and the overall median exposure levels measured in urban areas were less than 1 $\mu W/cm^2$. About 98-99% of the population would appear to be exposed to levels meeting even the very strict Soviet standard. However, 1 or 2% of the general population may be exposed to higher levels. For example, EPA measurements approached 2,000 $\mu W/cm^2$ at the base of a frequency modulated (FM) antenna on Mount Wilson, California. Measurements in excess of 180,000 $\mu W/cm^2$ were found on the FM tower itself, creating concern for workers who need to climb such towers. EPA has identified three major program uncertainties to be overcome in the nonionizing radiation area: existing ambient environmental levels and their rates and patterns of growth should be determined; criteria for specifying acceptable environmental levels should be established; and the existence of nonheating effects, which are potentially detrimental to public health and welfare, should be confirmed.

6654 BLOOD-BRAIN BARRIER WORKSHOP. *(Eng)* Benedick, M. H (IIT Res. Inst., 10 West 35th St., Chicago, IL 60616) [available through the Office of Naval Research, Arlington, VA 22217, IITRI Project No. E6456]; 18 pp.; 1979 (25 refs)

Studies of animals exposed to low-power pulsed or continuous wave microwave energy at frequencies ranging from 918 to 2,800 MHz and power densities ranging from 0.2 to 200 mW/cm^2 are reviewed to provide recommendations on whether additional research is required, to suggest design guidelines for future studies, and to evaluate the possible hazards to personnel. Studies thus far have not demonstrated conclusive evidence for blood-brain barrier alterations due to microwave irradiation on the order of 1 mW/cm^2 for short periods of time. However, conflicting results have been obtained concerning whether low-level microwave exposure causes an increase in blood-brain barrier permeability. Positive effects on the blood-brain barrier have been reported when the brain temperature was elevated from 37 C to 40 C by applying microwave energy to the brain. Positive results have also been observed when the brain temperature was increased by 0.4 C as a result of a 10-mW/cm^2 exposure. However, other studies have shown no evidence of penetration of radiolabeled substances using the Oldendorf method at exposure levels of up to 10 mW/cm^2. There appears to be no theoretical or experimental evidence that levels of microwaves that do not raise the brain temperature can affect the integrity of the blood-brain barrier.

6655 THE ENVIRONMENTAL PROTECTION AGENCY NEEDS CONGRESSIONAL GUIDANCE AND SUPPORT TO GUARD THE PUBLIC IN A PERIOD OF RADIATION PROLIFERATION. *(Eng)* Comptroller General of the United States (General Accounting Office, Washington, DC). [available through National Technical Information Services, Springfield, VA 22161, Document No. PB-276 107]; 94 pp.; 1978 (5 refs).

A report to the United States Congress by the Comptroller General discusses the need to better define radiation authorities assigned by law to the EPA so that jurisdictional confrontations may be eliminated and staffing and funding limitations may be corrected. The EPA received two authorities for providing radiation protection when it was created in 1970. First, it can issue standards for radioactivity in the environment, including general environmental

guidelines for particular industries and for radiation doses to the general public. Second, it can issue guidance to the appropriate Federal agencies affecting all forms of radiation protection in Federal activities. To date, EPA, under these authorities, has issued one standard (which has not yet taken effect) and has issued no new formal guidance. EPA's program for monitoring radiation levels to which the American people are currently exposed is limited. It does not know the scope of the dangers caused by all current radiation sources and so is unable to adequately anticipate all future problems.

MEETING ABSTRACTS

6656 BIOLOGICAL REACTIONS TO WEAK RF FIELDS: DEMONSTRATED SENSITIVITY, HYPOTHESIZED MECHANISMS (MEETING ABSTRACT). *(Eng)* Adey, W. R. (Jerry L. Pettis Memorial VA Medical Center, Loma Linda, CA). *In: Proceedings of the 146th National Meeting of the American Association for the Advancement of Science held Jan 3-8, 1980 in San Francisco, CA.* p. 64; 1980 (no refs).

Biological reactions to weak radio frequency (RF) fields are reviewed. While clinical applications of RF energy have typically involved fields of high strength, there are many indications that weak fields may play some important therapeutic roles. Data on small animals indicate that properly applied electric or magnetic fields at certain modulatory or carrier frequencies can: 1) augment the action of psychotropic drugs, 2) selectively alter in neural tissues the flux of calcium ion, 3) stimulate changes in humorally and cellularly-mediated immune reactions, and 4) influence bone metabolism and growth. The mechanisms by which these field-tissue and field-cell interactions take place must be elucidated for the full medical potential of RF energy to be realized.

6657 BEHAVIORAL AND PHYSIOLOGICAL REACTIONS TO INTENSE RF FIELDS (MEETING ABSTRACT). *(Eng)* Chernovetz, M. E. (Faculty Social Behavioral Sciences, Univ. Tulsa, Tulsa, OK). *In: Proceedings of the 146th National Meeting of the American Association for the Advancement of Science held Jan 3-8, 1980 in San Francisco, CA.* p. 64; 1980 (no refs).

Behavioral and physiologic reactions to intense radio frequency (RF) fields are reviewed. Exposures of short duration to highly intense RF fields have been studied in the laboratory and administered in the clinic (diathermy) since the advent of d'Arsonval's pioneering work in the late 19th century. Millions of diathermy treatments have been administered in therapy of both minor and major ailments, but the paucity of reports of adverse reactions has yet to be supported by experimental studies of animal models that would permit assessment of long-term sequelae. The experimental data on acute reactions are generally consistent with the thesis that morbidity and mortality result from hyperpyrexia akin to that resulting from excessive heating by conventional sources of thermal energy. One striking difference lies in the behavioral response to elevation of body temperature by highly intense and penetrating RF fields: physical collapse and death can occur without indications that the excessive heating is painful. Indeed, there is much anecdotal and experimental evidence to support the view that highly penetrating RF radiation at sublethal intensities has analgesic properties.

6658 PHYSICAL AND BIOPHYSICAL FUNDAMENTALS OF MICROWAVES AND OTHER RADIO-FREQUENCY ELECTROMAGNETIC RADIATIONS (MEETING ABSTRACT). *(Eng)* Guy, A. W. (Bioelectromagnetics Lab., Dept. Rehabilitation Medicine, Univ. Hosp., Seattle, WA). *In: Proceedings of the 146th National Meeting of the American Association for the Advancement of Science held Jan 3-8, 1980 in San Francisco, CA.* p. 64; 1980 (no refs).

The biophysical fundamentals of radio frequency (RF) electromagnetic radiations are reviewed. The RF spectrum of electromagnetic energy extends in 12 bands from just above direct current (0 Hz) to 3 terahertz (10^{12} Hz), above which lie the spectra of infrared and visible energies. The extent to which an incident RF wave is captured by and penetrates into a biologic body is highly dependent on wavelength and on the geometry and dimensions of the body in relation to the field. When RF waves are absorbed by a biologic body, both Joule currents and dielectric relaxation of molecules occur that result in translation of radiant to thermal energy. In addition, there may occur intermediate, charge-related transductions that, while energetically trivial, may be informationally or deformationally consequential. The complex relation of field structure and strength (densitometry) to absorption of RF energy (dosimetry) are discussed in the light of empirical and analytical data. Problems of measurement and interpretation are also discussed, especially that of extrapolation to the human being of data based on small animals. The quantities of energy absorbed per unit mass by a human being in microwave (300 MHz-300 GHz) fields are substantially less than those of the mice and rats upon which most experimental work has been performed. The failure to account for this factor of electrical scaling is one of several sources of faulty judgment concerning the harmful potential of microwave fields for man.

6659 DIAGNOSTIC AND THERAPEUTIC APPLICATIONS OF RF WAVES (MEETING ABSTRACT). *(Eng)* Sutton, C. H. (Dept. Neurosurgery and Pathology, Univ. Miami Sch. Medicine, Miami, FL). *In: Proceedings of the 146th National Meeting of the American Association for the Advancement of Science held Jan 3-8, 1980 in San Francisco, CA.* p. 64; 1980 (no refs).

The recent advances in utilization of microwaves and other radio frequency (RF) radiations for physical diagnosis and in cancer therapy are reviewed. A technique that exemplifies diagnostic innovation, which is already in limited clinical use, combines radiometry of the human body's endogenous emissions of infrared and microwave energy to detect breast cancer. This technique is equal to xeromammography in diagnostic accuracy and, as it is completely noninvasive, presents no risk to the patient from radiation. An example of this technique is the combined application of microwaves and x-irradiation in treatment of malignant melanoma. The dose of ionizing radiation can be reduced without loss of therapeutic efficacy. Applications that are in clinical use or are undergoing experimental trials on animal models are discussed in relation to biomedical, regulatory, and economic problems that are retarding research and development.

6660 RATIONALES FOR MICROWAVE AND RADIOFREQUENCY EXPOSURE LIMITS (MEETING ABSTRACT). *(Eng)* Czerski, P. (Dept. Genetics, Natl. Res. Inst. Mother and Child, Warsaw, Poland). *In: Proceedings of the 146th National Meeting of the American Association for the Advancement of Science held Jan 3-8, 1980 in San Francisco, CA.* p. 65; 1980 (no refs).

The development of rationales for microwave and radio frequency exposure limits are reviewed. In the 1950s, the first proposals were made for occupational microwave exposure limits (EL), 10 mW/cm^2 in the United States and 10 μW/cm^2 in Russia. Unfortunately, no published documents explaining the rationale for the proposed values were associated with the original recommendations. Considerable controversy has developed after the publication of the proposals and their explanations. During the last decade advances in microwave bioeffects research and in the exchange of scientific information have made possible both an understanding of the reasoning behind the original differences and a reassessment of the EL. Newly determined EL have been introduced in Poland, Sweden, and Canada with published rationales. The gap between values permitted in various countries is narrowing. However, further research is needed to improve existing standards. The existing permissible EL cover broad frequency ranges. As evidence of frequency-dependent bioeffects materializes, the standards may adopt values for dependence on narrow frequency bands or even on specific frequencies. Other research questions concerning microwave bioeffects remain unanswered. Long-term effects on development and inheritance need further elucidation. Studies are needed to identify and examine the basic biophysical mechanisms underlying the interaction of the radiations with living systems.

6661 MICROWAVE EFFECTS ON *STREPTOCOCCUS MUTANS* (MEETING ABSTRACT). *(Eng)* Leiby, T. (Dept. Microbiology, Univ. Texas Health Science Center, San Antonio, TX 78284); Moody, E. E.; Frazer, J. W. *Tex J Sci* 31(4): 377-378; 1979 (no refs).

The effects of microwave frequency of 1.1 GHz, for varying time intervals on *Streptococcus mutans* viability were examined using the spread plate technique. Cells received an average power of 4 W over the designated time intervals. Cell suspensions of *S. mutans* were prepared in a low conductivity solution to prevent ambient heating, and temperature as well as forward and reflected powers were monitored. Significant temperature changes in suspending solutions were not observed. Exposed cell suspensions, serially diluted and plated on Todd-Hewitt agar using the glass L-rod spreading technique, were incubated for 48 hr at 37 C. Colony forming units (CFUs) were recorded and compared to control levels. Exposed cultures consistently showed reductions in CFUs below control levels with exposure times between 1 and 5 min. Exposure times greater than 5 min resulted in colony counts above control levels. Increased CFUs appeared to result from reductions in chain lengths. Decreased CFUs may have been associated with a "skipping" of a cell division cycle. Based on the Helmstetter-Cooper model, this probably occurred during the initiating phase of cell division.

6662 EFFECTS OF GROWTH MEDIA ON MICROWAVE IRRADIATION OF *CANDIDA ALBICANS* (MEETING ABSTRACT). *(Eng)* Lutton, C. W. (Dept. Microbiology, Univ. Texas Health Science Center at San Antonio, San Antonio, TX 78284); Frazer, J. W.; Moody, E. E. *Tex J Sci* 31(4): 378; 1979 (no refs).

The long-term biologically propagated effects of microwave irradiation on a dividing cellular system were assessed. The experimental design permitted the evaluation of thermal pulsing on cell cycle synchronization. *Candida albicans* was grown 24 hr in BHI medium or Phytone Peptone medium plus 10% glucose. Aliquots of the prepared organism were irradiated at 1.1 GHz frequency. Forward and reflected powers were measured and temperature was monitored during irradiation. Relative dielectric constants of irradiated solutions were calculated. Surviving colony forming units were assayed after 24 hr at 25 C. BHI increased conductivity of the solution, shun-

ting the electromagnetic field around *Candida albicans* and caused growth inhibition, where as Phytone Peptone raised intracellular conductivity of *Candida albicans* and caused growth stimulation. The results demonstrate effects that are surface phenomena or intracellular phenomena depending on the media. The effects were not due to thermal pulsing.

6663 TOTAL BODY HYPERTHERMIA INDUCED BY A COMPUTERIZED MICROWAVE TECHNIQUE: STUDIES IN NORMAL AND TUMOUR-BEARING RATS (MEETING ABSTRACT). *(Eng)* Johnsson, P. E. (Dept. Surgery and Radiation Physics, Univ. Lund, S-221 85 Lund, Sweden); Hafstrom, L.; Bolmsjo, M.; Persson, B. *Br J Surg* 66(12): 899-900; 1979 (no refs).

Total body hyperthermia induced by microwave radiation was tested to evaluate the selective lethal effect of supranormal temperature on malignant cells. Wistar rats (200 g), with or without transplantable adenocarcinoma in the liver, were used. Under ether anesthesia, a Pt/Ir thermocouple was placed retroperitoneally adjacent to the aorta with the tip below the diaphragm. The animals were kept isolated in a plexiglas cage, which was placed in a larger plexi cage with a constant temperature (25 C). Siemens (Radioterm 305) Magnetron at 2.45-GHz maximum and a 200-W microwave generator were used. The exposure was below 4,000 W/m^2. The temperature probe signal from the animal was digitalized and fed to a computerized control system (INTEL 8085 microprocessor) with a 16-Kbyte memory. This system directed the microwave generator through a set of relays to a predetermined temperature in the animals of 41.5 C or 42 C for 1 or 2 hr (3x/24 hr). The microwave generator was turned off for a period of 4 sec before the temperature reading to avoid microwave-induced interference. The temperature was recorded each 30 sec. The temperature in the animals was also recorded in other parts of the body. The influence of hyperthermia on the survival and on tumor growth was registered. The computerized microwave generator induced a precise hyperthermia (±0.2 C) to a predetermined temperature for exact duration and intervals. The temperature registered in other parts of the body varied in relation to the guiding probe (±1 C). The central temperature of 41.5 C for 1 hr (3x/24 hr) caused a 70% survival. Longer duration or higher temperature increased the mortality significantly. No difference in survival between tumor-bearing and non-tumor-bearing rats was seen. A reduced tumor growth was observed during the first 3 days after hyperthermia.

6664 ULTRASTRUCTURAL STUDIES ON THE EFFECT OF LOW FIELD INTENSITY MICROWAVE RADIATION ON THE MEMBRANES OF LEAF CELLS OF RED KIDNEY BEANS (*PHASEOLUS VULGARIS* L.) (MEETING ABSTRACT). *(Eng)* Dwivedi, R. S. (Dept. Botany, Howard Univ., Washington, DC); Vaidya, C. B. *J Cell Biol* 83(2, Part 2): 279a; 1979 (no refs).

Red kidney bean plants (*Phaseolus vulgaris* L., 1-4 wk old) were treated with 2.450 MHz microwaves at field intensities of 5 mW/cm^2 and 10 mW/cm^2. Small pieces of leaf samples selected at random were prepared for electron microscopy after glutaraldehyde-osmium fixation. The membranes of leaf chloroplasts of 1- to 2-wk-old plants treated with microwaves at field intensity of 10 mW/cm^2 were totally disrupted; mitochondrial, endoplasmic reticular, and nuclear membranes were fragmented and vesiculated. Similar but less severe damage occurred in the membranes of leaves of 3-wk-old plants. Four-wk-old plants that received 10 mW/cm^2 exhibited even less damage to the cellular membranes of the leaves. At a field intensity of 5 mW/cm^2, the degree of damage to mitochondrial and endoplasmic reticular membranes was greater than that to chloroplast membranes, suggesting a differential susceptibility of membranes at this field intensity. The age of the plants also affects their general susceptibility to microwaves. The results suggest that membranes are the primary targets of microwave irradiation. Similar damage was caused by continuous and pulsed modes of radiation, suggesting that red kidney bean plants (*P. vulgaris* L.) experience some nonthermal effects of microwaves.

6665 MICROWAVE ILLUMINATION: (a) THAWING PATTERNS IN DIFFERENT OVENS USING DIRECT MEASUREMENT AND THERMOGRAPHY (b) USE OF A NON-CONTACT METHOD TO MONITOR THE EFFECTIVE DIELECTRIC TEMPERATURE CHANGE DURING THAW (MEETING ABSTRACT). *(Eng)* Guttman, F. M. (Dept. Surgery, Sir M. B. Davis Jewish Hosp., Montreal, Canada); Bosisio, R. G.; Bolongo, D.; Segal, N.; Borzone, J. *Cryobiology* 16(6): 608; 1979 (no refs).

The effects of microwave thawing of six froxen (-80 C) canine kidneys, perfused with 1.4 M Me_2SO, carried out in Toshiba and Litton ovens were compared. Direct measurement confirmed by thermography showed more irregular heating in the Litton. Two of six kidneys were burned at the hilum by the Litton whereas there was more uniform heating with the Toshiba. A noncontact, resonant perturbation technique measured the dielectric properties of the thawing organ. An active closed-loop oscillator was frequency is dependent on the load inside the oven was added. A direct measurement of this frequency signal by an automatic frequency counter was printed out by a digital recorder via a BCD output on the counter thus continuously monitoring the effective dielectric temperature (EDT) of the work load. EDT measurements of solutions of 0, 5, 10, 15, and

20% Me_2SO showed a low slope of change for the lower concentrations at 0-20 sec and then a rapid increase. Small kidneys exhibited a continuous curve and larger kidneys a discontinuous one, demonstrating the need for a larger oven for larger kidneys. Thus, microwave thawing controlled by a microprocessor seems to be feasible through the use of nondirect sensing frequency perturbation technique. Connection to a programmed microprocessor would also allow oven designs that ignore the problem of magnetron sensitivity to variations in the high-voltage power supply and in the axial magnetic field used to obtain crossed field interaction.

6666 SELECTIVE TUMOR HEATING BY SHORTWAVE RADIOFREQUENCY (RF) (MEETING ABSTRACT). *(Eng)* Auda, S. P. (Dept. Surgery, Univ. Maryland, Baltimore, MD); Steinert, H. R.; Elias, E. G. *Int J Radiat Oncol Biol Phys* 5(Suppl. 1): 31; 1979 (no refs).

Experimental tumor masses were treated with external high frequency dielectric heating to observe any selectivity among tumor mass, subcutaneous tissue, and systemic temperatures. Methylcholantrene-induced sarcoma cells were inoculated into the muscles of the posterior thigh of isologous Fisher rats. After 14 days, when the size of the tumor mass averaged 1.10 cm^1, radio frequency (RF) dielectric heating was applied locally to the tumor-bearing area. A fixed frequency of 13.56 MHz was used. The power needed to bring the tumor temperature to ≥43 C ranged from 0.5 to 0.8 W/cm^2. The temperature was gradually increased to 43 C and then maintained at or above that level for 1 hr. Thermocouple probes were inserted directly into the subcutaneous tissue immediately above the tumor and into two distinct areas of the tumor itself. Systemic temperature was monitored via a mercury thermometer inserted into the rectum. Temperature recordings were taken at 5-min intervals during which time the power was turned off to avoid RF interference and to allow thermal equilibrium between the probe and the tissue. The results indicated that there was a highly selective temperature gradient with tumor mass. A highly statistical significance ($p<0.002$) was found comparing the tumor mass, subcutaneous tissue, and systemic temperatures using Scheffe's test. The systemic temperature was minimally elevated throughout the treatment. In animals without tumors who were treated in the same fashion, there was no significant difference between the temperatures measured in the subcutaneous tissue and in two different sites in the thigh muscle mass. At this dosage, no tumor regression was observed.

6667 PHASE I-II STUDY OF IRRADIATION AND HYPERTHERMIA ON HUMAN NEOPLASIAS--PRELIMINARY FINDINGS (MEETING ABSTRACT). *(Eng)* Perez, C. A. (Washington Univ. Sch. Medicine, St. Louis, MO); Kopecky, W. J.; Baglan, R.; Rao, V.; Johnson, R. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 171-172; 1979 (no refs).

Twenty-five patients with 40 superficial lesions were treated at the Henry Ford Hospital in Detroit, MI according to a nonrandomized two-part protocol: 1) hyperthermia alone for 43 C (±0.5) for 90 min and 2) 400 rads radiation followed immediately by hyperthermia for 43 C (±0.5) for 90 min. In addition, 25 other patients were treated on a Radiation Therapy Oncology Group (RTOG) randomized protocol comparing three fractions of 500 rad followed by hyperthermia (42.5 C, 90-120 min) with three fractions of irradiation alone of 600, 700, or 800 rads each delivered every 72 hr. Irradiation was delivered with electrons or superficial x-rays and occasionally with ^{60}Co. Hyperthermia was given using a 2,450 MHz or 950 MHz microwave generator with suitable waveguide applicators. Temperatures at the surface and in the depth of the tumor were measured using a 24-gauge thermistor probe and recorded on a dual channel strip chart recorder. The hyperthermia was started immediately following the exposure to irradiation. Temperatures are measured at tumor depth, tumor surface, and normal tissue near the tumor in the microwave region. Skin temperatures were found to be within 39-41 C with the nonrandomized two-part protocol and around 42 C (±0.5) with the RTOG protocol. Fractions were separated by 72-96 hr. The tumors that were treated were confined to the skin, subcutaneous tissue, or to superficial lymph nodes. The fractionation scheme was sequentially modified to seek the optimal tumoricidal effect with a minimum normal tissue reaction. Fractions increased from 3, 5, 6, 8 to 10. The follow-up examinations were given 1x/wk for the first 4 wk, 1x/mo for the next 2 mo, and then 1x every 3 mo. Tumor regression was noted in every case. There was no significant short-term normal tissue reaction seen in any patient regardless of the number of fractions. Preliminary results of this study including effects of fractionation on tumor regression and normal tissue effects will be analyzed. Using serial tumor measurements (2 diameters) percent tumor regression will be calculated and regression curves will be generated according to tumor size, dose of irradiation given and, if enough patients are available, according to tumor location and histology. The regression of tumors treated with radiation alone will be compared with those treated with combination of irradiation.

6668 CLINICAL HYPERTHERMIA: RESULTS OF THE PHASE I CLINICAL TRIAL COMBINING LOCALIZED HYPERTHERMIA WITH OR WITHOUT RADIATION (HIGH DOSE RATE AND LOW DOSE RATE) (MEETING ABSTRACT). *(Eng)* Manning, M. R. (Div. Radiation Oncology, Arizona Health Sciences Center, Tucson, AZ 85724); Cetas, T.; Boone, M. L.; Miller, R. C. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 173; 1979 (no refs).

The clinical efficacy of local hyperthermia alone or in combination with radiation (high and low dose rates) is being analyzed in 40 patients with accessible local disease that failed to respond to conventional therapy including surgery, irradiation, and chemotherapy. Four patients were treated by a specific protocol for multiple metastatic subcutaneous nodules. Each had a minimum of three nodules treated differently: 1) 43 C for 40 min by radio frequency heating with needles placed on either side of the lesion acting as electrodes; 2) radiation from two radium needles treating to a dose of 4,000 rads in 100 hr; and 3) the same dose plus heat to 43 C for 40 min using the radium needles as heating electrodes. In this small group, significant differences in response to treatments were seen. There was an 80-90% response rate to the heat-radiation combination with complete disappearance of that lesion in three patients. A 50% response rate occurred in the heat alone and radiation alone groups. No adverse reactions were seen except enhanced erythema, dry desquamation, and one burn of less than 1 cm in diameter. These data suggest a beneficial therapeutic ratio and minimal side-effects from combined radiation-hyperthermia. The histologies treated were anaplastic parotid carcinoma, melanoma, and adenocarcinoma. The other 36 patients had advanced, accessible local neoplasms treated with heat alone, heat with an external beam or radioactive implant, or heat plus Cis-platinum. Histologies were: adenocarcinoma from breast, squamous cell carcinoma of the head and neck, malignant fibrohistiocytoma, melanoma, one osteogenic sarcoma, and rectal adenocarcinoma. The latter group's response rate for tumors treated with hyperthermia only was 50% (≥50% reduction in size). This was usually transient with the lesion recurring within 1 mo. One patient being followed was free of disease for over 3 mo. Those treated with a combination of local heating and external radiation to low total doses had a 70% partial response rate. Several patients had complete regression. The longest lasting was 3 mo. A small group of patients had interstitial ^{192}Ir therapy using the hollow needle guides as heating electrodes for a radio frequenty generator. An 80-90% response rate was achieved. Complete responses occurred in three patients. Overall, no significant adverse normal tissue effects were seen.

6669 MICROWAVE INDUCED CRANIAL HYPERTHERMIA AND CANCER THERAPY (MEETING ABSTRACT). *(Eng)* Michaelson, S. M. (Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14642); Quinlan, W. J.; Iu, S. T.; Wilson, G. A.; Zagars, G. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 174; 1979 (1 ref).

Dogs were exposed cranially to 2,450 MHz continuous wave (CW) microwaves to determine if adjuvant therapy with microwaves enhances the effectiveness of chemotherapy and/or radiotherapy in the treatment of malignant brain tumors such as glioblastoma multiforme or astrocytoma. The dogs were exposed cranially to 2,450 MHz CW microwaves by means of contact applicators to produce brain temperatures of 39-42 C for 1 hr, while maintaining skin temperature below 44 C. Tc-99m pertechnetate brain scanning was used to evaluate the changes produced by the microwaves. The dogs were imaged prior to, immediately after, and up to 2 wk post-microwave exposure. Images were digitized and analyzed by computer techniques. At low absorbed microwave doses minimal change was noted. With increasing microwave intensity, however, Tc-99m uptake in the brain increased. These results suggest a methodology for producing localized hyperthemia in the brain as an adjunct therapy for radiotherapy and/or chemotherapy or to provide a means for enhancing the ability of chemotherapeutic agents to cross the blood-brain barrier for greater therapeutic effectiveness against leukemia and brain cancers.

6670 EFFECTS OF LOCAL HYPERTHERMIA ON TUMOR MICROCIRCULATION: I. BLOOD FLOW RATE STUDIES (MEETING ABSTRACT). *(Eng)* Emami, B. (Dept. Therapeutic Radiology, Tufts Univ. Sch. Medicine, New England Medical Center Hosp., Boston, MA 02111); Nussbaum, G.; TenHaken, R.; Hahn, N.; Hughes, W. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 175; 1979 (1 ref).

A noninvasive technique, employing in situ photon activation-^{15}O positron decay technique, was utilized to study the effects of local hyperthermia (radio frequency) on capillary blood flow in transplanted tumors (rhabdomyosarcomas-BA1112) of WAG-Rij rats. Blood flow was measured before and at varying intervals after heating. Multiple time-temperature combinations were tested. Typical blood flow rates, without hyperthermia, ranged between 44 and 15 ml/min/100 g of tumor tissue. Heating up to 42 C for 30 min caused only slight reduction in tumor blood flow, whereas heating to 44 C for 1 hr resulted in almost complete cessation of blood flow at 10-min, 3-hr, and 24-hr post-heating.

6671 EFFECTS OF LOCAL HYPERTHERMIA ON TUMOR MICROCIRCULATION: II. PATHOLOGICAL STUDIES (MEETING ABSTRACT). *(Eng)* Piro, A. J. (Dept. Therapeutic Radiology, Div. Lab. Animal Medicine, Tufts Univ. Sch. Medicine, New England Medical Center Hosp., Boston, MA 02111); Emami, B.; Nussbaum, G.; Hahn, N.; Dristschilo, A.; Engler, S. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 176; 1979 (no refs).

Groups of WAG-Rij rat transplanted tumors (rhabdomyosarcoma-BA1112) were treated with local hyperthermia (radio frequency). Various temperatures (ranging from 38 to 43 C) were utilized

and the results of observations on microcirculation were analyzed. Parallel groups of animals, with tumors heated exactly the same way, were subsequently sacrificed at 1, 3, and 24 hr after heating and tumors were subjected to detailed pathologic studies for evaluation of the effects of heat on microcirculation as well as on tumor cells. The results are indicative of no specific changes in microvasculature up to 40.5 C. At intermediate temperatures (42 C), vessels showed marked dilatation and congestion. At higher temperatures (44.5 C), there was massive hemorrhage and necrosis with rupture of vessel walls. The degree and intensity of this process also depends on the interval between heating and time of sacrifice of the animal.

6672 CELL SURVIVAL AS A DETERMINANT OF TUMOR CURE FOR RAT 9L SUBCUTANEOUS TUMORS FOLLOWING MICROWAVE-INDUCED HYPERTHERMIA (MEETING ABSTRACT). *(Eng)* Wallen, C. A. (Dept. Radiation Biology and Biophysics, Univ. Rochester, Rochester, NY 14642); Feldstein, M. L.; Michaelson, S. M.; Wheeler, K. T. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 198; 1979 (1 ref).

The relationship between cell survival and tumor cure after treating 9L subcutaneous tumors in rats with microwave-induced hyperthermia was investigated. Tumors were grown by implanting subcutaneously 10^6 9L rat brain tumor cells from 2-day-old cultures into the inguinal region of male Fisher 344 rats. Tumors weighing 200-400 mg were locally heated to 42.5, 43.0, 44.0, and 45.0 C by exposure to 2,450 MHz microwaves using a rigid coaxial contact applicator. Temperatures beneath the tumor were monitored throughout the exposures with copper-constantin thermocouples. Cell survival data were obtained by excising the tumor immediately after treatment, trypsinizing to single cells, and then plating to assay for clonogenic survival. From this data, survival curves were constructed for each temperature as a function of exposure duration (0-180 min). At each temperature, the response curve was best described by a simple exponential, $S = e^{-\alpha t}$, with the value of alpha increasing as temperature increases. Tumor cures were monitored during 90 days following exposure to 44 C for 0-120 min or at various temperature-time regimens that gave a predicted cell survival of approximately 0.3%. Tumor cures were exponentially related to the time at 44 C, with 50% cures occurring after an exposure of approximately 20 min. Exposures at different temperature-time regimens that gave the same surviving fraction immediately after treatment did not result in the same percent of tumor cures.

6673 A LABORATORY AND CLINICAL ASSESSMENT OF 434 MHz MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). *(Eng)* Johnson, R. (Roswell Park Memorial Inst., Buffalo, NY); Subjeck, J.; Knowal, H.; Moreau, D.; Yakar, D. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 215; 1979 (no refs).

A comprehensive in vitro, in vivo, and clinical study of 434 MHz hyperthermia was performed to substantiate clinical reports of 434 MHz hyperthermia by other investigators. To simulate clinical conditions in in vivo experiments, the effect of 915 MHz hyperthermia on V 79 survival was investigated with and without radiation, using microwaves at a measured temperature of 41 C (nonthermal equilibrium conditions); the results were compared with results obtained using waterbath-heated controls. In in vitro studies, thermal distributions for both 915 MHz and 434 MHz microwaves were obtained to depth of 10 cm in pigs both with and without skin cooling. The clinical study investigated surface cooling of patients with multiple metastases who had been treated with 434 MHz microwave hyperthermia. Radiation doses of 100-400 rads were used with post-radiation hyperthermia of less than 41 C to simulate previous studies by other investigators. Preliminary results demonstrated that cell survival was significantly decreased by high microwave powers and measured temperatures of 41 C as compared with 41 C waterbath conditions. In vivo studies of temperature distributions in the pig demonstrated that 434 MHz was superior to 915 MHz. Surface cooling provided 43.5 C hyperthermia to a depth of 5 cm, with surface temperatures of 30 C. Minimal heating occurred at 10 cm. The results demonstrate that the clinical thermal distributions are variable. Homogenous heating may be maintained in some patients to 5 cm in depth. The effect of the 434 MHz microwaves in conjunction with radiation on tumor response and regrowth will be investigated.

6674 CLINICAL EXPERIENCES WITH LOCAL MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). *(Eng)* Luk, K. H. (Claire Zellerbach Saroni Tumor Inst., Mount Zion Hosp. and Medical Center, San Francisco, CA); Purser, P. R.; Castro, J. R.; Meyer, T. S.; Phillips, T. L. *Int J Radiat Oncol Biol Phys* 5(Suppl. 2): 215-216; 1979 (no refs).

Thirty-eight patients, at the Claire Zellerbach Saroni Tumor Institute, Mount Zion Hospital and Medical Center, San Francisco, CA, with superficial observable lesions of a variety of histopathologic diagnoses were given 49 courses of hyperthermia between December 1976 and December 1978. A typical course of hyperthermia treatment consisted of six to nine 1-hr fractions delivered in a period of 2 or 3 wk. Localized hyperthermia was induced by microwave irradiation using two Federal Communications Commission approved frequencies; 27 patients received 38 courses of 2,450 MHz diathermy and 11 patients received 11 courses of 915 MHz diathermy.

Radiotherapy was combined with hyperthermic treatment in 38 of 49 courses, with tumor radiation doses ranging from 1,500 to 4,200 rads. Tissue temperatures were monitored with in-dwelling thermistors and average tumor temperatures ranged from 38.4 to 42.9 C. Local tumor responses were recorded and will be correlated with tissue temperature and radiation dose combinations. Complications arising from the induction of local tumor hyperthermia by microwave radiation will be analyzed.

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This quarterly digest presents current awareness information on the biological effects of nonionizing electromagnetic radiation (microwave and radio frequency) in the range of 0 Hz to 100 GHz. The effects of magnetic and electric fields (static and alternating) are also covered. Each issue contains abstracts of English and foreign current literature, summaries of ongoing research investigations, news items, and a directory of meetings and conferences.

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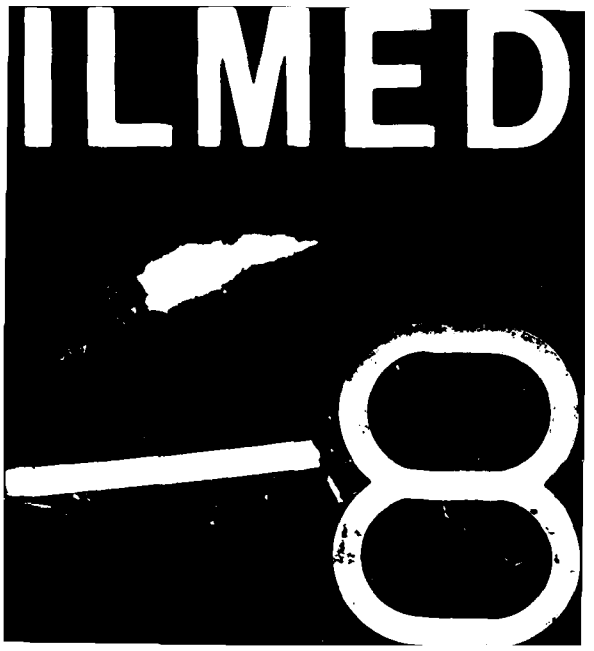
14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
biologic effects						
electric fields						
electromagnetic						
magnetic field						
microwaves						
nonionizing radiation						
radio frequency						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